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Table of Contents

List of Figures

List of Tables

List of Acronyms

ABV	Aniva Bay Vessel
API	American Petroleum Institute Arctic Oil Spill task group
CMT	Crisis Management Team
CREO (aka Ecospas)	OSR PERT, Contractor of Sakhalin Energy
Ecoshelf	OSR PERT, Contractor of Sakhalin Energy
ECT	Emergency Coordination Team
EMS	Emergency medical services/systems
ERMT	Emergency Response Management Team
ERR	Emergency Response and Rescue
FRDC	Fast rescue daughter craft
HDB	Heavy-Duty Boom (Ocean Heavy Boom)
HSE	Health, Safety and Environment
ISB	In-situ Burning
JIP	Joint Industry Programme on Oil Spill Recovery in Ice
LAB	Lamor Auto Boom (light single-point boom)
LAS	Lamor Arctic Skimmer
LUN	Lunskoye
LWS	Lamor Weir Skimmer
MOB	Marine Operations Base
NEBA	Net Environmental Benefit Analysis
NERT	Non-Professional Emergency Response Team
OPF	Onshore Production Facility
OSPR	Oil Spill Preparedness and Response
OSR	Oil Spill Response
OSRP	Oil Spill Response Plans
PAA	Piltun Astokh A
PAB	Piltun Astokh B
PERT	Professional Emergency Response Teams
PMD	Pipeline Maintenance Depot
PPE	Personal Protection Equipment
PSV	Platform Supply Vessel
PTS	Pig Trap Station (Station for receiving and launching a pig, its maintenance and diagnostics)
RDP	Rapid Deployment Packs (for OSR mobile package of equipment stored in 5 foot containers placed on a stand-by truck)
SBV	Stand-by Vessel (ERR and OSR duties)
SC	Site Controller
SCBA	Self-contained breathing apparatus
TLU	Tanker Loading Unit

Terms and Definitions

Ablation	is the natural melt of snow and ice from an ice surface downwards through various processes, including evaporation, temperature increase, and wind erosion. Ablation can refer either to the process of removing ice and snow or to the quantity of ice and snow removed.
Biodegradation	is the process where naturally occurring bacteria and other micro-organisms consume hydrocarbons to use as a food source.
Brash ice	Accumulations of floating ice made up of fragments not more than 2 m across; the wreckage of other forms of ice.
Dissolution	is the process where water-soluble compounds in a surface oil slick dissolve into the water column below.
Drift ice	Masses of ice floating in an open body of water moving under the influence of winds and currents
Emulsification	is the process of mixing water droplets into the spilled oil forming highly viscous mixtures that have reduced weathering capabilities and are usually more difficult to burn, disperse and mechanically recover.
Evaporation	is the preferential transfer of light- and medium-weight components of the oil from the liquid phase to the vapour phase.
Fast ice	Type of stationary ice in seas, oceans and bays.
First year ice	Sea ice of not more than one winter's growth, developing from young ice with a typical thickness varying between 30 cm and 2 m.
Flaw lead	aka Polynya or Polynia
Frazil ice	A collection of loose, randomly-oriented needle-shaped ice crystals in water.
Grease ice	Accumulations of thin layers of crystalline congealing ice (with greasy appearance) usually associated with the early stages of freezing.
Hummock	A hill-type pile of broken ice formed as a result of compression.
Hummocked ice	Sea ice with a random pile of fragments forming an uneven surface. Upon melting, these fragments look like smoothed hummocks.
Ice cake	Any relatively flat piece of sea ice of less than 20 m across.
Ice keel	The submerged part of an ice ridge.
Ice roughness	A combination of irregularities on ice surfaces that impact air or water flow in or near ice layers.
Ice types by age	Spring ice (formed before current summer), year-old or first year ice (passed the winter) and multi-year ice (existing two winters at least)
Ice types by development stage	New (frazil ice, grease ice, cream ice), young (pancake ice, ice rind, nilas, grey ice, white ice) and multi-year (pack) ice.
Ice types by location	Fast ice (stationary ice frozen to a shore) and pack ice.
Ice types by origin	River, sea, glacier-type ice.
Landfast ice or fast ice	Stationary sea ice that has frozen along coast, shoals, or to the sea floor over the shallow part of the continental shelf, and extends out from land into sea
Multi-year ice	Ice that has not melted during the summer, and existing for two winters at least.
Natural Dispersion	is the process of breaking waves forcing oil droplets into the water column, which can result in at least a portion of the droplets small enough to remain in the water.
Oil Spill	A release of oil or petroleum products in a water body, on land surface, or into ground water, irrespective of causes and circumstances of the release.
Oil Spill Clean-up	Activities aimed at the restoration of a facility and/or life-support facilities affected by an emergency, to ensure their normal operation; environmental rehabilitation to a state which excludes any adverse impact on human health, animal and plant life.
Oil Spill Containment	Activities that prevent oil and oil products from spreading further over land and/or water surface.
Oil Spill Response	Recovery and utilisation of spilled oil and oil products
Pack ice	A large expanse of floating sea ice, driven by wind and ocean or sea currents

Pancake ice	Round-shaped ice plates, ranging from 30 cm to 3 m in diameter and approximately up to 10 cm thick, with elevated rims caused by collision with other ice plates.
PERT	Professional Emergency Response and Rescue Team: independent entities or parts of an existing emergency response and rescue service, specifically designed for the execution of emergency response and rescue operations and equipped with dedicated machinery, equipment, gear, tools, and materials.
Polynya or Polynia (aka flaw lead)	is an area of open water surrounded by sea ice; it is also a geographical term for areas in the Arctic which remain unfrozen for much of the year.
Pour Point	is the temperature at which oil will cease to flow.
Sea Ice concentration	The ratio (in tenths) expressing the total proportion of sea water surface covered with ice in a given area.
Sludge ice	Finely broken or half-formed ice on a body of water usually forming as the result of wind and/or wave action.

INTRODUCTION

Scope

Development projects for the extraction and transportation of petroleum products in the coastal waters of Sakhalin Island have resulted in, public authorities and local citizens expressing concerns with regard to oil spills that could have significant environmental consequences. These concerns are shared by Sakhalin Energy and stakeholders of the Sakhalin-2 project. Managing and reducing the potential risks of a spill is recognised as an integral part of the project.

Oil Spill Response Plans (OSRP) for each Sakhalin Energy production Asset have been developed and applied to the Assets operations to minimize the risks, size, and effects of a spill. A low probability of spills and high performance in Oil Spill Preparedness and Response (OSPR) are the primary factors in implementing of the project and help maintain Sakhalin Energy's excellent reputation. Thus far, Sakhalin Energy has developed and successfully implemented a comprehensive OSPR Strategy.

Offshore Sakhalin Energy Assets are located in the coastal zone of the Sea of Okhotsk, an area characterized by subarctic and arctic weather during the winter period. This means that snow, wind, low temperatures and ice-infested waters create complex conditions for an Oil Spill Response (OSR).

The presence of ice may complicate the implementation of OSR measures. Significant ice cover makes it difficult for ships to access the spill area and to assist in OSR operations. Ice cover also may limit the types of equipment and strategies to be deployed. On the other hand, ice cover impedes the spread of a spill, slowing down its dispersion, and reduces the rate of evaporation.

The ice conditions of Sakhalin, like many other cold regions world-wide vary considerably often on a daily basis or even hourly, and so general OSR principles must be researched, learned, and then implemented as appropriate to the time of a spill and throughout its duration.

This Manual focuses on strategies and tactics which are applicable for the ice and snow conditions common to Sakhalin Island and adjacent waters, as well as to comply with Sakhalin Energy OSR capabilities. Although a blend of general and specific technologies and techniques are included, all information is based on principles that have been investigated by researchers world-wide in labs, think-tanks and field work.

Today the Industry is taking proactive steps to develop modern tools and technologies to ensure that effective solutions are available to handle a potential spill. Sakhalin Energy constantly monitors the development of new technologies and tactics appropriate to OSR in ice. These technologies and tactics are evaluated in terms of their applicability to the Sakhalin Region and Sakhalin Energy capabilities.

The strategies and tactics of this Manual are based on techniques described in the Spill Tactics for Alaska Responders (STAR) Manual, 2006. In this 3rd revision of the Manual changes reflect comments provided in mid 2012 by Environ/PCCI; WGWAP; and Counterspil Research Inc. Also the Manual was reviewed to incorporate strategies and tactics of the publication "Spill Response in the Arctic Offshore" prepared in February, 2012 by the American Petroleum Institute (API) Arctic Oil Spill Task Group and the Joint Industry Programme on Oil Spill Recovery in Ice (JIP); as well as the report summary "Spill Response in the Arctic Offshore" prepared in November, 2012 for the API and JIP on Oil Spill Recovery in Ice. Both of these publications describe the tools the industry will utilise in the event of a spill in the Arctic.

Sakhalin Energy conducts training at offshore and onshore assets in cold weather conditions to generate information to serve as a basis for cold climate response. The information refers to response in a marine environment, shorelines, bays, rivers, and remote onshore areas.

The Field Guide sections "Response Tactics" described in this Manual reflects the actual field experience of Sakhalin Energy OSR experts as well as the skills of the Sakhalin-based OSR Offshore and Onshore Professional Emergency Response Teams (PERT) Ecoshelf and CREO.

This 3rd revision of the Manual replaces Rev.01 and Rev.02 of the Oil-in-Ice Manual (0000-S-90-04-P-0152-00). A current controlled copy of the Manual is stored in the LiveLink system. The user of this document should check its current revision in advance. If any assistance or comments are required, please refer to the OSR experts of Sakhalin Energy Emergency Response Management Team (ERMT).

Purpose

This Manual was developed to provide Managers and Responders with a source of systematic information to help them plan and select response strategies and tactics appropriate for ice conditions.

The Manual also provides technical information suitable for training purposes.

To a lesser extent, it can be used as a reference document to be consulted in the event of a spill but in no way replaces Sakhalin Energy Assets OSRPs which detail the likely fate and behavior of spills, specific response actions to be taken, contacts to be alerted and notified, and organizational structures.

The Manual is intended for use in combination with Sakhalin Energy OSRPs.

This Manual is intended to facilitate selection of suitable, practical, and feasible response strategies and tactics appropriate to ice and snow. The strategies described are standardized and may not be applicable to every distinct situation. Since each oil spill is unique, Responders may apply methods outlined in the Manual but should act in accordance with the limitations imposed by prevailing conditions.

The Manual contains primary strategies to help Responders to investigate the location of a spill, determine the size, delineate the oil slick, and predict the oil spill trajectory onshore and offshore. It further describes how to correctly define slick borders and includes information regarding actions to be taken if oil is covered with snow.

The Manual discusses the current state of knowledge regarding response strategies during freeze-up and winter periods (December to April) as well as a break-up period (May to June).

SELECTION OF RESPONSE STRATEGY

This Manual serves as a technical resource for Responders to implement practical tactics in winter conditions. Tactics and equipment described in this Manual specifically address the work environment which exists on Sakhalin Energy assets. Spill response must include flexibility and access to all available tools and strategies to stop the discharge, contain the spill, and combat the oil. Company and contractor experts in various fields must be involved in the process of decision making and planning of OSR operations in ice. Please see appropriate OSRP to find additional information regarding the person in charge – who shall conduct non-mechanical response techniques and identify resources should these response measures be selected and approved for use.

After an oil spill, urgent decisions need to be made about how to minimize environmental and socio-economic impacts. Responding to an oil spill is challenging under any circumstance, but ice conditions require additional considerations. Before selecting one or more response strategies to deal with a spill in ice conditions and mobilizing equipment, decision-makers must obtain information on a variety of factors, including the size and type of spill, local weather and sea conditions, the presence, concentration, and characteristics of ice on site of the spill, the spreading and other spill characteristics.

Decision should be based on the following principles:

- If possible, an oil spill should be cleaned up or destroyed before it gets close to the shoreline, because shoreline response costs and environmental damage are many times greater than offshore.
- An important factor which governs all decisions about response strategies is the Net Environmental Benefit Analysis (NEBA). NEBA helps decision-makers determine which response strategy (i.e. mechanical recovery, dispersants, or ISB) will minimize environmental harm. Decision to apply any of OSR actions must be based on NEBA.
- The selection of the most appropriate strategy for spills in ice will not only strive to achieve the highest net environmental benefit, but also take full account of serious safety issues which govern offshore operations under winter conditions of extreme temperatures and ice. In some cases, safety concerns will necessitate a “Monitor and Wait” approach rather than attempting a risky marine operation, which might also have very limited chance of success. Safety considerations must be central to the development and implementation of strategies and tactics for response not only for the purpose of prevention of harm to response personnel, but also to avoid delays in execution of response strategies which may occur when someone is injured and must be assisted or rescued. Response objectives must never be allowed to compromise safety.
- The success of oil spill response operations is largely dependent on the time necessary to make decisions and mobilize oil spill response resources. The relative contribution of each process varies depending on the type of oil, duration of the spill, and weather and sea conditions. Due to the changes in the oil’s properties, the possibility for the use of various oil spill response countermeasures also changes. But in ice-covered waters time-dependent weathering may be significantly reduced depending on ice type, ice coverage and energy conditions. This can be an advantage and contribute to the improved response effectiveness for some oil spill scenarios.
- It is important to note that, although discussion and analysis of oil spill response capabilities often focuses on large-scale response to a significant offshore spill, applicability of certain response techniques may differ for smaller spills or those which occur near shoreline or onshore. In Tier 1 spills, preference should be given to mechanical recovery.
- In Tier 2 and 3 spills, one should give equal consideration to all oil spill response options. The advantages and disadvantages of different responses need to be

compared with each other. The chosen oil spill response techniques should be used concurrently. The primary strategy should be to address the spill as close to the source and as far offshore as possible, and implement source control operations in the event of an ongoing discharge. Beyond the immediate vicinity of the source, aerial dispersant applications should be used to treat oil which has escaped near-field mechanical booming and recovery efforts. Further from the source both dispersant application and mechanical recovery using available vessels should be deployed to combat floating oil. Accurate targeting of oil through visual observation and remote sensing from aerial and other vantage points should be a key component of the response.

The basic decision-making procedure offered on Figure 1 is recommended for use in any tire of spill.

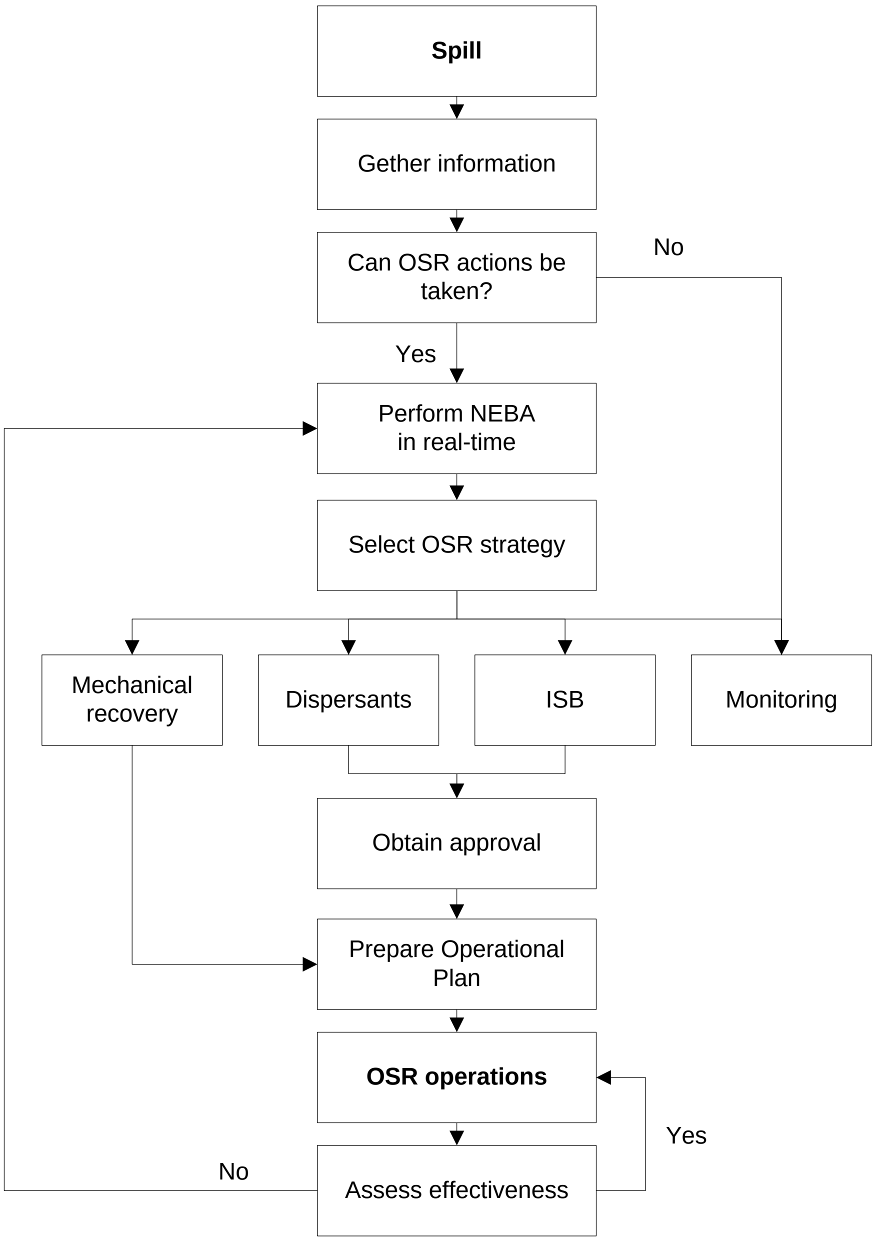

Figure 1 Decision-making flowchart

As said above strategies are intended to be flexible. Responders may and should adjust or modify them to meet the prevailing conditions resulting from such factors as weather, ice, snow, currents, wind, oil properties, time of spill, and available capabilities and resources, considering that:

- size, shape, thickness, concentration and velocity of ice are not static;
- wind shifts in direction and speed may be frequent;
- wind largely determines ice position as well as oil trajectory;
- oil spilled into ice will likely interact with it;
- the relative position of oil and ice will change over time.

Basic OSR planning requires estimates of the extent of the ice cover and its characterization – the amount and type of ice present dictates which approaches should be tried to control a spill and the safety precautions which must be taken. One way of planning the use of potential countermeasures in ice is Figure 2 which shows Mechanical and Non-Mechanical Response Tactics for specific ranges of ice cover. This figure is for planning purposes and so it indicates the countermeasures that should be considered, realizing that ice conditions are dynamic and so specific ice concentration limits for countermeasures are not exact, nor is precision always needed or applicable.

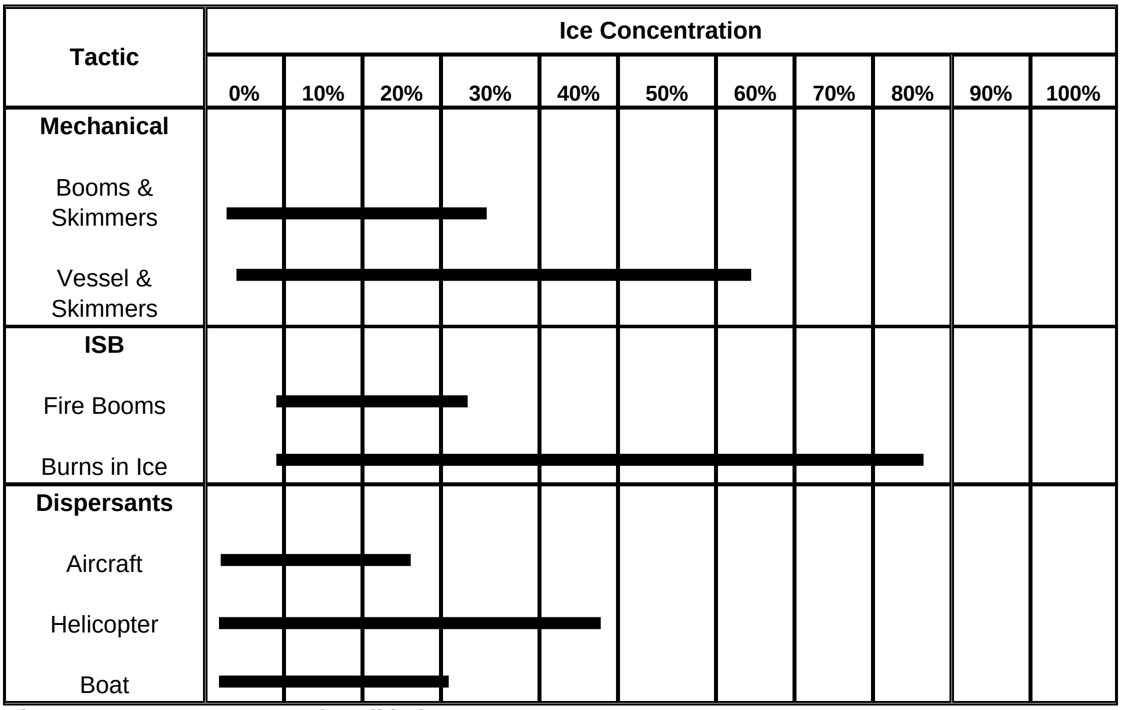

Figure 2 Countermeasures for oil in ice

When crude oil is spilled at sea, a number of natural processes take place which change the physical and chemical properties of the oil, called weathering. These natural processes are evaporation, water-in-oil emulsification, oil-in-water dispersion, release of oil components into the water column, spreading, sedimentation, oxidation and biodegradation. Oil spilled in ice and, in particular, under ice, is difficult to detect and collect, or even to model its trajectory. In some cases, the exact spill location will be in doubt. Therefore it is important to understand the fate and behaviour of oil in ice before attempting to detect spilled oil during the winter so that OSR operations can be planned and conducted successfully. Find this information in the subsequent sections of the Manual.

BEHAVIOUR AND FATE OF OIL IN ICE

When responding to a spill in ice-infested waters, it is critical to understand how oil will behave in these conditions. Spill response in Sakhalin region requires extensive knowledge of challenges and opportunities which must be taken into consideration.

- Ice, snow and cold temperatures can greatly reduce the spread of spilled oil.
- Oil biodegrades in all marine environments, including ice- infested waters.
- Oil trapped within ice in the winter typically emerges at the surface during spring thaw.
- Encapsulated oil released due to spring thaws acts similarly to oil spilled in open water.

The following discussion summarizes the key processes governing the fate and behaviour of oil spilled in ice conditions. While many of the processes and countermeasures are applicable to freshwater ice environments, the focus here is on saltwater conditions representative of the continental shelf region, marginal ice zone, sub-Arctic area as Sea of Okhotsk.

The presence of ice affects the behaviour of oil. Generally, evaporation and physical dispersion rates are reduced by ice and cold water. The viscosity of the oil increases, which reduces the rate of formation of an emulsion or oil entrainment in rivers and streams. Ice presence affects slick movement at sea by slowing down the rate of spreading.

In ice infestations, where oil spreads less quickly, slicks generally remain thicker, partially due to the fact that in cooler water oil becomes more viscous, but mainly due to the containment effect of the ice.

In areas of free water, oil will drift to the leeward edge of the ice where it will merge with sludge ice. Eventually this oil mixed with ice might be covered with snow. The behaviour of spilled oil in ice depends on a number of processes as shown in Figure 3 below.

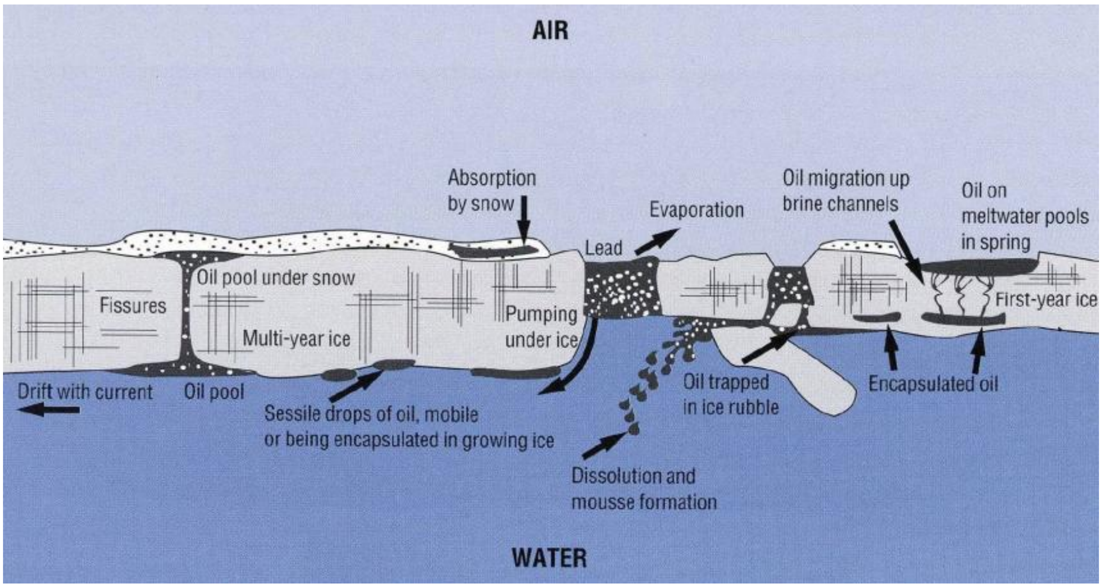

Figure 3 A schematic composite displaying a number of possible configurations of oil in ice (Bobra and Fingas 1986)

Spreading

The presence of ice and low water temperatures reduces the rate of spreading and drifting of spilled oil. Evaporation and emulsification processes will also be reduced in ice-infested waters. Similarly, land fast ice will keep offshore oil from impacting shorelines from freeze-up to break-up.

On ice

Oil spreading on ice is similar to its spreading on land. Spreading rate is determined by oil density and viscosity, while spread extent depends on ice surface roughness.

Even smooth first-year sea ice has considerable surface roughness, and discrete ice deformation features such as rafting, rubble and pressure ridges can lead to localized increases in roughness up to tens of metres in elevation above sea level. An oil spill on rough ice surface may be fully localized as a thick oil patch.

On snow

As a rule, ice covered with a layer of snow which absorbs the spilled oil prevents its further spreading. Oil spilled on solid snow will penetrate down to the ice level and continue to spread through the snow layer.

On cold water

Warm water oil spreading equations did not reasonably predict the results for cold, viscous oils and proposed a “viscosity correction factor” or substituting oil viscosity for water viscosity in spreading models (SL Ross and DF Dickins, 1987; Buist et al., 2009). If the ambient water temperature approached the Pour Point of the oil, spreading would cease. Because of this increase in viscosity, an oil slick on cold water is usually thicker and occupies a smaller area than it otherwise would in a more temperate climate.

In ice

In pack ice oil spills tend to spread far less and remain concentrated in greater thicknesses than in ice-free waters. In ice concentrations greater than 60 to 70%, the ice floes touch each other at some point and provide a high degree of natural containment. As the concentration of the ice floes diminishes, the potential for oil spreading among the more separated floes gradually increases until it approaches an open water state in very open drift ice (30% and less).

Under ice

Even large spills of crude oil underneath solid or continuous ice cover will usually be contained within relatively short distances from the spill source (compared with the equivalent volume spilled in open water), depending on under-ice currents and ice roughness characteristics. Natural variations in first-year ice thickness, combined with deformation features such as rubble and ridging provide large natural “reservoirs” to effectively contain oil spilled underneath the ice within a relatively small area.

When oil is released beneath growing sea ice, new ice will completely encapsulate the oil layer within a few hours to a few days as the ice continues to grow downwards (i.e., thickens), depending on the time of year.

After oil has spread under the ice and been encapsulated, it will remain trapped until the ice layer under which the oil has been encapsulated begins to experience spring thaw. During the period from freeze-up to mid-winter when the sheet is cooling and growing rapidly, there are very few passages for the oil to penetrate into the ice sheet. As ice temperatures gradually increase, brine trapped between the sea ice crystals begins to drain leaving vertical channels for the oil to eventually rise to the surface. Oil appearance on the ice surface would be observed in May.

Weathering

The main oil weathering processes include evaporation, emulsification, natural dispersion, dissolution and biodegradation. In general terms, the combination of cold temperatures, and reduced wave energy due to the presence of ice results in a reduced rate of weathering and an extended window-of-opportunity for effective response (Sørstrøm et al., 2010). Temperatures can significantly impact the natural weathering processes of oil.

Evaporation

Evaporation typically plays a significant role in the natural weathering of spilled oil and oil products. Following discharge, most crude oils and light products such as diesel and gasoline are subject to significant evaporation relative to heavier, more viscous oils, including bunker fuel and emulsified oils. However, oil spilled in sub-freezing temperatures evaporates more slowly than oil at higher temperatures. Furthermore, oil spills covered with snow exhibit even lower evaporation rates.

Emulsification

The formation of water-in-oil Emultions (also known as “mousse”) and the natural dispersion of oil slicks into the water column are processes driven by wind and wave action causing a mixing of oil and water. As such, these weathering processes are much less prevalent in ice, except at an ice field’s open-water edge, or under conditions in which moving ice floes may add surface turbulence. Wind waves (as opposed to swell) are effectively damped by the presence of pack ice.

Natural Dispersion

Oil is naturally dispersed into the water column where wind and waves are strong enough to break an oil slick into micron-sized droplets which disperse and dilute in the water column. The extent to which dispersion occurs depends on the oil type and the amount of ‘mixing energy’. This process is less prevalent in ice which can reduce or block waves.

Dissolution

Dissolution is a relatively minor weathering process (few per cent by volume) where the light ends of fresh oil can dissolve into sea water.

Crude oil contains a small amount of water-soluble compounds which may dissolve into the surrounding water. Components that undergo Dissolution in sea water are the light aromatic hydrocarbons compounds which are also those first to be lost through evaporation, a process which is 10-100 times faster than dissolution. Therefore dissolution is a relatively minor weathering process and would be relevant mostly for fresh oil finely dispersed in the water column. Dissolution rates in cold water are lower than those in warmer climates.

Biodegradation

Oil discharged into the marine environment is also subject to Biodegradation, the chemical dissolution of materials by bacteria or other biological means. Organic material like oil can be degraded aerobically with oxygen, or anaerobically, without oxygen. The biodegradation process reduces the adverse effects of the oil to the receiving environment by removing the hydrocarbons and also by degrading the more soluble components, which tend to be more toxic, first.

Petroleum is a complex mixture of many different types of chemical components primarily consisting of Carbon, Hydrogen, Oxygen and Sulphur. Interestingly these elements represent four out of the six principal elements, or chemical building blocks of living systems (Nitrogen and Phosphorus being relatively rare in petroleum). Carbon represents an average of about 85% of the petroleum by weight. Naturally occurring bacteria can utilize these elements as a “food source”. Hydrocarbon-degrading microorganisms have been found in almost all ecosystems (Margesin and Schinner, 2001; Prince and Clark, 2004). Biodegradation of hydrocarbons by microbial populations in the natural environment depends upon physical, chemical, and biological factors such as the composition, state, and concentration of the oil or hydrocarbons. Dispersion enhances the rate of biodegradation by increasing the surface area available for microbial attack and diluting the oil to the point that oxygen and available nutrients aren‟t exhausted (Lee et al., 2011).

OVERVIEW OF SAKHALIN ICE CONDITIONS

Sea conditions during the winter will not normally be a controlling issue due to the dampening effects of nearby pack ice. Exceptions could be situations where an offshore polynya is very extensive, allowing the sea to be churned up by wind-driven waves. Long period ocean swells can penetrate an offshore pack throughout the ice season but are not a critical operational factor.

The most important factor affecting response decision-making and the outcome of any offshore response during freeze-up and winter is the highly dynamic nature of the ice cover. Conditions are constantly changing as the pack opens up and comes together in a patchy, site-specific manner.

The annual pack ice regime offshore of Northeast Sakhalin is highly dynamic and variable. Freeze-up begins in late November or early December. Newly formed sea ice drifts offshore and to the south under the influence of prevailing NNW winds and a southerly current. Tidal currents superimpose circular ice movements on this net southerly drift. The average ice speed is approximately 0.5 m/s but speeds of over 0.8 m/s can be expected for about 10% of the time.

Eventually, pack ice extends out to between 75 and 100 km from shore. A recurring polynya is often present between the offshore pack and land-fast ice (a variable, frequently narrow fringe of continuous ice attached to the shore along the NE coast). The polynya opens and closes in response to wind shifts, closing when winds blow from the east or when westerly winds slacken. By late April or early May, the pack ice is reduced to small fragments of thick, rough floes (remains of winter rubble fields and ridges). The last remnants of the decaying pack have typically left the region by late May or early June.

Mid-winter conditions can cause a wide range of ice forms depending on the state of the polynya. Monthly average ice concentrations can range from as low as 2/10 ice cover to as high as 8/10. Over the entire winter period, heavy pack ice – defined as over 6/10 of medium first year ice (70-120 cm thick) – will likely persist for less than one month. Median floe sizes within the pack are approximately 100 m in diameter, with many floes as small as to 20 m in size. The average surface roughness of these floes is in the order of 1.25 m. In some seasons, the polynya dominates the offshore environment to such an extent that pack ice exists for only 15% of the ice season.

True open water conditions are short lived during the January to March period as openings in the pack are rapidly covered by grease and new ice. The thin new ice is constantly rafting and deforming under wind and current stress. Situations of static or very slow moving ice are rare and transitory (speeds less 0.1 m/s occur for only 10% of the time).

Extreme weather	Temperatures range from +25 to –35 °C Temperature offshore can drop to –50 °C with wind chill. Waves up to 10 m significant. Frequent fog occurs in spring and summer.
Ice season	Approximately 125 (160) to 195 (210) days. NE shelf ice from December until June.
Ice thickness	Thickness is inconstant around Sakhalin Island. Rafting of ice may significantly increase ice depth. Rubble formation and ridging increase both draft and height (surface elevation). Ice drifting from other areas may have greater thickness. Usually highly variable. NE shelf: from 5 to 150 flat ice (without roughness). Aniva Bay: from 5 to 30 flat ice (without roughness).
Ice concentration	At the end of the freeze up period (generally 15-30 days), maximum ice concentrations range from 9/10 to 10/10. The concentration of any ice in the area may vary from 0 to 10/10. When all ice types (thin to thick) are

	included, typical concentrations are generally 9/10 or more. However, the level of coverage does not fully describe ice conditions and level of operability.
Flaw lead	Flaw leads (polynya) are very thin ice (up to approximately 30 cm thick) with open water leads between the narrow land-fast ice zone and the heavier pack ice areas towards the east. These can persist for periods of days to several weeks during winter. Thin flaw leads are quite common at Piltun and Lunskoye as well as over pipeline routes, particularly during early January to mid-March. When a flaw lead occurs, it can result in thin drifting ice conditions (less than 30 cm thick) at platform sites and over the sub-sea pipeline to the coast (or to the landfast ice edge if it exists).
Ice floe size	NE (Northeast) Shelf: Floes may be of varying size, particularly in mid-ice season. There are reports of ice floes of less than 1 m across (pancake ice) up to more than 30 km across (giant floes). Typically, floe sizes are smaller during freeze-up, early winter, and break-up periods, with most floes being tens of meters to several hundred meters in size. In mid-winter, ice floes are characteristically larger, in the range of hundreds of meters to a kilometre or more. Aniva Bay: from less than 1 m (pancake ice) up to 1-2 km or more in length (big floes).
Ice drift speed	NE Shelf: quite variable, depending on winds and tidal currents. It can reach 170 cm/sec (more than 2 knots). However, on the average speeds are around 20-30 cm/sec. Generally, ice drifts along the island from N to S-SE approximately 6-8 km per day. Aniva Bay: from 1 to 15 cm/sec. Predominant ice movement is towards the S-SW.
Fast ice	A narrow strip of fast ice is typically found along shallow waters adjacent to the coast. This strip of ice attached to shore is very unstable and can appear and disappear a few times per season. Maximum estimated ice thickness is in the range of 1.6 to 1.7 m. Based on field measurements, rafted (or layered) ice areas in the fast ice have been reported to have an average thickness of 1.9 to 2.2 m with maximum values of 3.5 m in occasional drill holes.

DETECTION, MONITORING AND TRACKING

Detection and tracking of oil is essential for determining the location and extent of oil slicks, behaviour of a spill, and ice presence.

Detection, monitoring, and tracking of oil are key requirements for the appropriate allocation of resources during an oil spill response.

Information from on-site detection and monitoring identifies targets for immediate application of response tactics.

Trajectory Modelling of the future movement of spilled oil allows responders to adjust response plans for site specific factors, adapt to weather windows that may temporarily restrict operations, and to identify resources at risk so that appropriate protective measures can be applied.

Detection

In the case of a spill, the detection of oil in ice conditions is critical for determining what resources are required to quickly mitigate impact.

If oil is spilled during either the ice freeze-up or breakup period, visual detection and approximate estimation of the true area of contamination in open water leads (polynya) should not be problematic as less oil is hidden by slush and new ice. However, if ice concentration exceeds 7/10, oil may mix with ice rather than spread over the surface and, consequently, may be difficult to detect.

Factors which will dictate the effectiveness and capability to detect oil in any given spill situation include:

- composition and concentration of ice;
- visibility and ceiling;
- duration of daylight;
- ice drift; and
- rates and type of oil release (e.g. subsurface or surface).

There is no one sensor which will work across a broad range of oil in ice situations and weather conditions. Planning scenarios for oil in ice spill response should include a flexible combination of sensors operating from diverse platforms, including aircraft, satellites, vessels, helicopters, and on-ice teams.

Airborne remote sensing supplemented by visual observations of a trained observer remains the most effective method for identifying and mapping the presence of oil on water. Real-time information on ice conditions and oil location should be frequently communicated to the Site Controller (SC).

When a vessel approaches the area of an oil spill, the observer on the navigating bridge should make direct observations. A vessel has the ability to take oil samples which allows for an enhanced assessment of the state and thickness of an oil slick. This also reduces the risk of false identification, since oil slicks and natural phenomena such as wind drift may in practice appear very similar.

It is often difficult to differentiate between oil slicks and other phenomena such as silt on ice, algae blooms, cloud shadows on the water, and wind patches, all of which may appear similar to spilled oil. False identifications of oil are possible in the spring as the melting ice surface can appear dirty from earlier wind-driven ice and sediment deposits.

For situations in which slicks and natural phenomena are difficult to discern, the following tasks can be employed to aid in slick identification:

- Several different vantage points should be used to observe the oil in order to verify that it is indeed oil.
- Facing the sun and viewing with the sun at your back can give different results.

- Sunglasses can be tried to cut down the glare so that oil can be differentiated from ice, water, and sediment.
- Experienced spill observers should participate in the initial sighting and documentation of oil
- Only those with experience in the ice conditions of Sakhalin should be responsible for documenting the location and extent of oil in ice.
- In some cases, when oil has been trapped in ice, gas detectors can be used to help detect and locate oil.

Monitoring

Detection is not an issue in the case of a large visible spill around a damaged vessel or from a fixed exploration or production platform. However, continued monitoring and tracking of the oiled ice will sometimes be required in a dynamic pack ice environment where the spill source and the oil may become quickly separated by tens of kilometres. Over time the spill may become widely separated and cover a large area, further complicating the process of long-term tracking.

Oil in ice on water will move with the same speed and direction as drifting ice. Wind effects are greater on ice than on oil alone, with the result that oil in drifting ice can move faster than oil on open water given the same wind conditions.

Tracking

Tracking and forecasting the position of spilled oil, based on remote sensing information, environmental data, and numerical modelling provides information that can be used to direct airborne and marine response resources.

Numerical models can forecast future movement of oil based on the location of spill sources, remote sensing observations of oil location, and data on winds, ocean currents, and ice conditions. Forecasts of oil position provide information on resources at risk of impact so that protective measures can be appropriately applied.
Predicting the future position of spilled oil provides information that can be used to direct both airborne and marine resources, a crucial tactic in containing potential spills. Sources of tracking information include:

- high-resolution satellite imagery;
- the national ice services of a coalition of countries including Canada, Russia, United States, Denmark and Norway;
- oceanographic and meteorological services; and
- surveillance aircraft.

Outputs from spill tracking activities include:

- maps of real time and predicted contaminated area boundaries;
- vector representations showing movements of oiled ice; and
- charts showing the detailed composition of the ice cover where the oil is located such as: mix of floe sizes, variability in ice coverage, and boundaries of leads and polynyas.

On open water the approximate slick trajectory can be calculated by adding the surface current velocity and 3% of the wind velocity. These calculations are made using a “vector diagram”. Ice presence significantly affects the accuracy of these calculations. In a previous Revision 02 of the Manual this option had been described **but it works only for open water. Do not use that formula for ice conditions.**

The assessment of oil spill spread and its potential impact is based on computer modelling using Geographic Information System (GIS) technology. Trajectory Modelling considers the nature of the oil release (blowout, pipeline rupture, vessel wreck), oil properties, and relief peculiarities.

Because forecasting oil movement in ice is complex, the results of trajectory modelling may be unreliable. Computer models which Sakhalin Energy utilizes can calculate general patterns of oil transport and spreading but usually the lack of ice data limits the accuracy of the simulations. The model used by Sakhalin Energy is the OILMAPTM. This is a commercial model of the trajectory, behavior, fate and countermeasures for oil spills at sea developed by Applied Science Associates (www.asascience.com). The model can predict the trajectories for either instantaneous or continuous spills and considers spreading, evaporation, emulsification, natural dispersion, shoreline impacts and oil-ice interaction. The mass balance of the spill is predicted for the specific type of oil selected, based on a library of oils and their physical and chemical properties. Spill modelling in ice is very simplistic in this product and does not reflect the complexity of oil spill behavior in ice conditions.

Please see appropriate OSRP to find additional information regarding the person in charge, who shall conduct Detection, Monitoring and Tracking tactics, who has the capabilities and technology to do this and how these assets might be contacted and mobilized to support an oil-in-ice response efforts.

Adverse Weather

Adverse weather is defined as environmental conditions which may affect people, equipment, or facilities to such an extent precautionary measures must be taken to safeguard personnel and the facility, and to maintain a safe system of work.

Adverse weather includes snow, ice, fog, hail, lightning, heavy rain, high winds, low cloud base, poor visibility, extremes of temperature, severe sea states, and strong currents. In certain circumstances low or no wind can also be considered adverse weather. Weather conditions can change quickly and the effects of short-term variations, such as wind gusts, must be considered.

It is required to maintain awareness of the current and forecast weather situation.

Reasons for restricting deployment of OSR equipment may include:

- Aerial/marine vessels and crews are at risk due to adverse weather or sea state, or deployment of equipment will result in unacceptable safety risks to the vessel crew.
- Response equipment will not be effective due to high sea states, presence of ice, or other weather conditions.
- Oil is a thin sheen which cannot be recovered; the oil is expected to and is observed to be rapidly breaking up.

In accordance with Safety considerations there are risks either from the oil itself or from environmental conditions (weather, access, hazards, etc.). For offshore response in wintertime and during conditions when sea ice is prevalent, it may be that no active response strategies are usable. In this case, Monitoring and Tracking should be identified as the only viable “no response” option to simply monitoring and observing a slick.

RESPONSE TACTIC: BURNING OFFSHORE

The objective of this strategy is to create a controlled burn of spilled oil while it is pooled on water in ice. This strategy is most effective if used immediately after a spill, so that volatile components will initiate and sustain burning.

It is considered the optimal response strategy for most spills in broken ice when the following conditions are met:

- For effective and sustained burns, oil should not be more than 25% emulsified or more than 30% evaporated. Incineration of a 50% emulsion might be possible.
- A crude oil layer should be of sufficient thickness (≥2-3 mm) in order to avoid heat absorption by water.
- Crude oil should be incinerated within 2-3 days after the spill.
- Weathered, emulsified or heavy oil needs to be ignited at higher temperatures and will require catalytic agents. Sakhalin oils are light and likely to be initially combustible, but will become less combustible after weathering.
- Wind velocity should be lower than 10 m/s, and wave height has to be less than 1 m.

Basic strategy:

- Identify location and trajectory of spill and access points.
- Obtain regulatory approval.
- Plan burning to ensure that it is safely conducted and does not interfere with other on-water operations.
- Select equipment and configuration that best supports the operating environment.
- Mobilize personnel, response equipment and fire suppression equipment.
- Concentrate oil on the water surface to thickness of 2-3 mm using fire-resistant boom. Oil might also reach burnable thickness in flaw leads.
- Ignite the oil.
- Monitor the burn, ice type and concentration, oil and ice movement, wind speed and direction and the surrounding area to ensure safe operations and fire control.
- Remove all burn residue from the water surface. Some burn residue might be neutrally buoyant or sink.

In-situ incinerating systems on water generally consist of containment mechanisms, ignition and fire suppression means. Oil must be contained against ice edges in leads or within a fire-resistant boom.

Handheld ignition devices can be used for small, relatively fresh (i.e. unweathered) oil spills. For larger areas, helicopters with special ignition equipment may be used to ensure rapid ignition. Helicopters used in such operations may also provide aerial monitoring of the burning. When oil is ignited, it is actually the vapors that burn, not the liquid oil. In order for an oil slick to burn, the fire temperature must be high enough to maintain vapor flow.

Oil may be contained by ice and a decision might have to be taken to carry out in-situ burning in cases where oil is trapped in ice. An overall reduction of the spilled oil volume by 95% can be achieved when burning activities are conducted immediately after the spill in areas where ice prevents accumulated oil from spreading. Several different ignition locations may be necessary to eliminate separate oil slicks. Burning efforts should focus on oil accumulated with thick layers at ice edges. During a period of landfast ice, grease and slush ice may interfere with burning. Generally, the in-situ burn strategy is most effective during ice breakup and when polynyas are formed.

Large ice arrays may contain significant amounts of oil in under-ice pockets. During spring, oil that has accumulated under ice may migrate to the water surface through splits and cracks as well as through brine channels. Concentrations of accumulated oil released by ice may also be incinerated.

Oil trapped within the growing land-fast ice zone, but not spread over the surface, may be released with help of an ice-breaking vessel. Incineration may melt ice thus releasing submerged oil which is trapped underneath.

A Heli-torch device is a method of igniting oil which ensures controlled burning of an oil slick at sea. A Heli-torch sets fire to an oil slick by dropping burning portions of thickened fuel onto it. The device is suspended under a helicopter and controlled from the helicopter's cabin. Sakhalin Energy has two Heli-torch devices stationed at the Nogliki PMD. This type of device is used worldwide for ignition of spilled oil on open or ice-covered water.

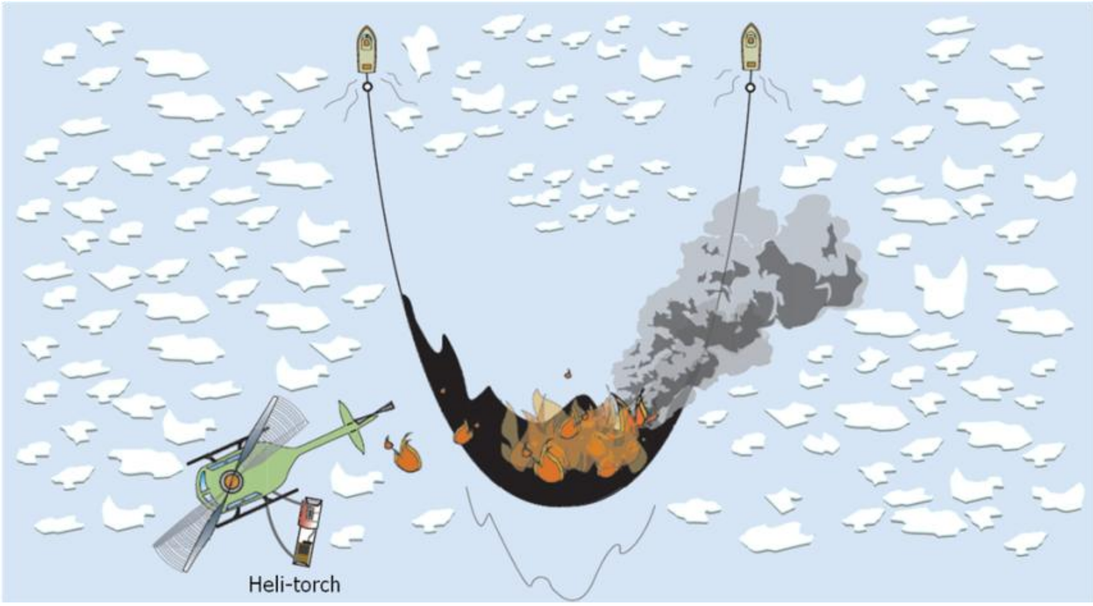

Figure 4 Ignition of oil with the use of a Heli-torch (STAR Manual 2006)

Approval will be sought from Sakhalin Government Authorities; no burning will be undertaken without approval.

- ensure that an assessment by experts is performed in advance of employing this tactic;
- consider the possible effects of smoke on responders, populated areas or wildlife;
- consider respiratory protection: respirators with organic vapour cartridges must be readily available in case the wind shifts;
- ensure communication and clear understanding of roles and responsibilities which are crucial to execution and safety during the burn process;
- anticipate and prevent secondary fires;
- monitor wind conditions to ensure fire control; burning operations should not take place in winds exceeding 15 knots;
- ensure that fire-retardant clothing and other PPE is worn by responders as required;
- consider that refined products generally burn more efficiently and produce less residue but can contain products of combustion with higher toxicity; and
- remove burn residue from the site.

Sakhalin Energy is not considering the option to utilize burning tactic onshore. That's why RESPONSE TACTIC: BURNING ONSHORE is not included in this Manual.

RESPONSE TACTIC: DISPERSION OFFSHORE

The task of dispersants is to ensure chemical dispersion of spilled oil on the sea surface. Dispersants do not remove the oil but break it into very small droplets which are mixed in the upper layer of the water column where biological degradation can occur. The application of dispersants in cold water has been recently recognized world-wide.

Dispersants are usually sprayed from an airplane, a helicopter, or a vessel. Accurate targeting is essential to ensure effective application of dispersants, but the importance of factors such as droplet size, concentration, rate of application, and dosage play a significant role as well.

The basic strategy when applying dispersants includes the following:

- identification of the location and extent of a slick;
- mandatory approval by supervisory authorities;
- calculation of the volume of dispersants needed, application dosage, and application rate;
- application of dispersant to the thickest sections of the oil slick; and
- monitoring of the application process using the appropriate protocols to ensure accuracy and effectiveness, and to prevent misapplication.

All spray systems consist of tanks for dispersant storage, a power source, a pump, control valves and metering equipment, spray arms, and nozzles (see Figure 5 below). Spray systems must be able to produce the appropriate dosage and droplet size. Prior to usage, systems must be calibrated to the specific dispersant type.

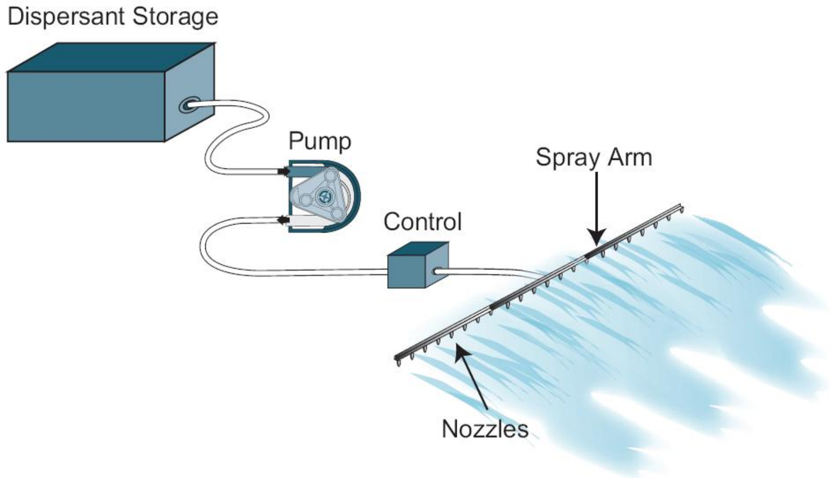

Figure 5 Dispersant Application System (STAR Manual 2006)

Before application, a test spray should be conducted where dispersant is sprayed on a small portion of the oil slick to determine if droplets form. Dispersants should be applied to oil slick areas of moderate or greater thickness, not onto sheen areas. Application runs should begin at the edge of the slick and proceed using parallel, continuous runs, treating the slick from up- or downwind (as opposed to crosswind).

Dispersants applied by an airplane cover a larger area than vessel-based applications and are effective for treating oil slick with concentrated dispersant on open water. Operational range, fuel consumption, turnaround time, payload, and the ability to operate from short or improvised landing strips are all important factors to be considered. In addition, aircraft should be capable of operating at low altitude and relatively low speeds (50-150 knots) while remaining highly manoeuvrable.

Helicopter application systems have the benefit of having the ability to adjust speed and therefore application rate. Limitations are small load size and short flying time and distance. Rotary-wing aircraft can be configured to use either an internal or, more commonly, an underslung bucket application system. In general, helicopters have a faster transit speed than vessels, even when carrying a slung load. The hovering ability of a helicopter also makes it ideal for some nearshore operations.

Vessel-based application tactic

Vessel-based applications operate more accurately with oil in ice. Vessel-based systems provide the ability to adjust dispersant dosage during operations and more selectively treat slicks which may lead to more effective application and dosing. Vessels which are used to spray dispersants need to be equipped with a boom system and an adapted fire monitoring system or ducted fan. Boom systems spray dispersant through a set of nozzles fixed on outboard booms. Typically, booms are mounted as far forward as possible to ensure that the dispersant is applied ahead of the bow wave created by the vessel. This helps to mix the dispersant and oil more effectively.

Figure 6 Example of a dispersant spray system (Photo: Jason Engineering AS)

The following points should be taken into consideration involving dispersant application:

- Dispersants are only effective on non-viscous oils (generally <2,000 cSt.) and should be applied to slicks of relatively fresh (less than 48-72 hr old) thick oil.
- Vessels spraying dispersants are generally restricted to sea states of less than 4 and winds of less than 22 knots.

Sakhalin Energy PSVs (Platform Supply Vessels) ("Supply boats") are equipped with Dispersant Spray Systems. The dispersant tank onboard is up to 30 tonnes of volume; also the system includes a pump and easily deployed spray booms. There are a total 2 booms (1 starboard and 1 port sides). Each boom is about 10 meters in length. The booms are mounted in such a way as to bring nozzles close to the sea surface (2.5 m), but at the same time at a safe distance from waves and ice. The spray system is mounted closer to the bow to ensure direct contact with oil prior to mixing by the bow wave, and to minimize the herding effect. The picture above demonstrates example of spray booms in deployed mode.

The Offshore Non-Mechanical Response Strategy – in ice concentration 10/10 – is in utilizing of icebreaking vessels to open the ice floe; then to apply dispersants in a targeted manner (to the exact point); and after that to use the azimuthing thrusters of PSVs to provide the mixing energy (e.g. Figure 7 and Figure 8 below). This mixing energy is required to create very small droplets to ensure that the droplets remain suspended and diffuse throughout the water column with the limited natural turbulence present under the ice cover; otherwise the oil would simply rise back to the underside of the ice after the vessel moved on.

Figure 7 Lateral mixing of ice by the icebreaker using azimuthing thrusters to clear a channel (PSV Pacific Enterprise, Sakhalin Energy, March 2008)

Figure 8 Lateral mixing of ice by the icebreaker using azimuthing thrusters to clear a channel (PSV Pacific Endeavour, Sakhalin Energy, March 2006)

Approval and Rules

"Rules for the Use of Dispersants for Oil Spill Response" is the approved code for use of dispersants in Russian Federation. These Rules meet IMO, Helcom and Russian Governmental Authority recommendations and are in compliance with Russian Federation legislation. Sakhalin Energy has the Net Environmental Benefit Analysis (NEBA) for Piltun-Astokh Field. There is the recommendation for not using dispersants within 20-meter isobaths in the Piltun Feeding Area of Western Grey Whale, but outside of this area dispersants could be used. In any case dispersants application tactic discussed in this Manual is for the winter season, when there are no whales in the field. The NEBA, Rules, as well as, International Best Practice recommends to not use the dispersants in the sea water shallower than 10 m. Decision-makers must keep this in mind and notify on-site responders to follow these recommendations.

The Rules states that a decision to use dispersants must be based solely on the NEBA of an area which has been polluted or is under threat of pollution. Decision-makers must realise that they are required to follow the NEBA and that it is required to make the current operational assessment of the actual situation at the area exposed to pollution. The Rules states that dispersants should be used when an NEBA shows that avoiding their use will have a greater adverse impact on biological resources and the economy. It is require to realize that if a particularly oil-sensitive resource would be contaminated by oil, the use of dispersants could be used to prevent this from occurring. The dispersants is a good option for Offshore OSR Strategy to prevent potential shoreline and bays (lagoons) oiling. If the decision to use dispersants is made, it is required to do the best to use the Window-of-Opportunity according to NEBA, follow the logic, NEBA, operational assessment on the day of a spill, and guided by the "Rules for the Use of Dispersants for Oil Spill Response".

RESPONSE TACTIC: MECHANICAL RECOVERY OFFSHORE

Mechanical containment and recovery is considered the primary or preferred response strategy in many regions of the world. Containment booms are normally used in combination with a skimmer to remove oil from the water surface where it is temporarily stored before being processed and disposed of. Environmental and oceanographic conditions as well as the spilled oil's physical properties are taken into account to determine the type of mechanical equipment best suited for oil recovery. Oil spreads less and remains concentrated in greater thicknesses in broken ice compared to open water.

Skimmers for oil removal, booms for containment and prevention of slick spreading, and pumps for transferring it to a collection site are key components of this strategy. This equipment and the various strategies for applying it to oil-in-ice situations using mechanical methods are reviewed below.

Strategies related to oil containment and collection using mechanical methods assume implementation of measures to create a greater concentration of oil in certain areas for increasing film thickness, thus improving the effectiveness of oil collection.

Resources On-site

Sakhalin Energy Platform Supply Vessels (aka "Supply boats")

Ice breaking and ice management techniques have changed in the last few years. This was possible due mainly to azimuth type propulsion systems being installed on a new generation of ice breakers. Sakhalin Energy vessels (see Figure 7 and Figure 9) are equipped with Aquamaster type thrusters which provide exceptional manoeuvrability and station keeping. The powerful propeller wash which is achievable in all directions breaks up ice with ease.

Offshore platforms require a continuous supply of equipment and marine cover. This is achieved through the use of ice class Pacific supply boats. Ice class DNV Ice-10 Platform Supply Vessels (PSV) are used on the Sakhalin-2 project. These vessels are designed to reach a constant speed of 1.5 knots in first year ice which is 1.5 m thick. They are also capable of breaking ice and making sternway in a 4 m polar ice pack. Being equipped with high power Aquamasters, they can turn 180 degrees in less than 90 seconds as well as clear an escort channel 70 meters wide in 0.5 m of first year ice. Each PSV is equipped with a dispersant spray system.

Figure 9 PSV Pacific Endeavour (bow) (PA field, December 2009)

Sakhalin Energy OSR/ERR Stand-by Vessels (aka “Stand-by boats”)

OSR/ERR Stand-by vessels (SBV) carry ice notation Lloyds 1A super, Canadian Arctic Class 4. These vessels provide the ability to selectively manage ice by breaking down large floes and manoeuvre in heavy ice conditions (see Figure 12 below). This procedure has the potential to transfer oil trapped on top of the ice or underneath the ice into the water (this may or may not be beneficial depending on the scenario and response strategy selected).

Figure 10 Sakhalin Energy SBV Smit Sibu on Duty (bow), the (P-A field, December 2009)

Figure 11 SBV Smit Sibu on Duty (aft) with OSR Vessel Kit on board (P-A field, February 2009)

Figure 12 Sakhalin Energy SBV ex-Smit Sibu in heavy ice on the Piltun-Astokh Field (March 2007)

SBVs fulfils their ERR and OSR duties 24/7/365 and provide support in areas where Sakhalin Energy marine platforms are stationed – one at the Northern Piltun-Astokh field and one at Lunskoye. They have a guarding function which warns ships in transit to stay 5 km away from the platforms, ensure safety during helicopter flights, and assist during outboard work on the platform. On-duty vessels clear ice near platforms in winter. In case of emergency, the vessels will assist in evacuating personnel from the platform, provide support during search-and-rescue operations in a man-over-board situation or a helicopter accident, and assist in fire extinguishing activities in the event of fire on a platform (e.g. deployment of a water curtain). There is a vessel with OSR duty in Prigorodnoye at the TLU area quite similar to the vessels keeping watch at the NE shelf but with less ice class. An OSR vessel kit is placed on board each SBV.

If an oil spill occurs, the vessels will deploy OSR equipment and act in conformity with the OSRP. Full deployment of the OSR Vessel containment and recovery system takes about 1 hour from the request to mobilize.

The list of equipment onboard the multi-function support vessels comprises oceanic and arctic containment and oil-recovery systems. There are two different booming systems, i.e. 600 m of Heavy-Duty Oil Boom and 75 m of Light Oil Boom of the Side Sweep System. There are four skimmers, i.e. two weir skimmers and two oleophilic brush skimmers.

Sakhalin Energy Harbour Tugs (aka "Port tugs")

Operations in Prigorodnoye require support of harbour tugs. Sakhalin Energy operates four purpose built ice class 1A tugs equipped with Aquamaster propulsion system (Z drive). The four harbour tugs are designed for escort work in ice. The tugs are designed to operate in up to 80 cm of level ice at a minimum of 3 knots, perform harbour ice management, and, when operating in pairs, break a channel wide enough for the tankers calling at the terminal.

In addition to Prigorodnoye SBV these tugs are able to deploy OSR equipment stored at the Marine Operations Base (MOB). OSR equipment is not permanently kept on board but booms can be obtained and deployed directly from an onshore concrete ramp (slip) designed for boom deployment on water; and skimming systems as well (similar to what is included in a typical OSR vessel kit).

Figure 13 Svitzer Tugboat (Prigorodnoye Port, December 2008)

Contain

Containment Boom Tactic

In open water booms are usually required to contain and thicken spills for mechanical recovery. A conventional booming strategy is most effective in open water with ice concentrations below 3/10.

Single vessels with an over-the-side skimming (Side Sweep) system using short sections of boom can manoeuvre between large ice floes and operate in higher ice concentrations than vessels towing independent booms. This tactic could be deployed but is not recommended in the Sakhalin ice environment due to the fact that ice concentration can change quickly; also Side Sweep outriggers and booms are very light, and the risk of damaging them is high.

Figure 14 SBV with deployed Side Sweep Contain System; using short sections of boom and manoeuvring to catch oil (OSR training at Prigorodnoye, Sakhalin Energy, September 2011)

The objective is to contain the oil slick with a boom on the water surface, best done as close as possible to the spill source to minimize spreading of oil.

A boom may be deployed around a moored vessel or in an area where oil was spilled from a sub-sea pipeline. The boom can be deployed in various configurations so that it surrounds a release from a tanker loaded from a TLU or from a ruptured sub-sea pipeline.

Usually, this tactic is related to oil transfer operations from one vessel to another, or from a vessel to the shore and vice versa.

The containment booming tactic could be deployed by the SBV jointly with its own FRDC or the nearest PSV in a U- or J-formation. However, deployment of a J- or U-type boom is generally not recommended in ice since there is a high probability that the boom will be damaged when it collides with large, sharp blocks of ice (see Figure 15 below: boom deployed in massive pancake ice). An even greater risk exists in relation to the increase of tension created by the continuous accumulation of small, broken ice fragments in the pocket. Eventually, the boom or rigging may not withstand the forces acting against it, which could result in damage of the total structure, causing the contained oil to be released again.

Figure 15 Example of massive ice pieces. Boom deployment in pancake ice (Sakhalin Energy oil in ice training, December 2009)

Deflection Boom Tactic

The mechanical recovery system which is used in ice-infested waters intended to deflect ice in order to gain access to the oil and effectively remove it.

The Deflection Tactic is applied to water-borne spills where there is a current, usually from approximately 0.5 to 2.0 knots. The boom is placed at an optimum angle to the oil trajectory, using the movement of the current to carry oil along the boom to a recovery location. The angle is chosen to prevent oil from entraining beneath the boom skirt, i.e., the resultant velocity perpendicular to the boom is less than approximately 0.75 cm/s (0.5 m/s= 1 knot).

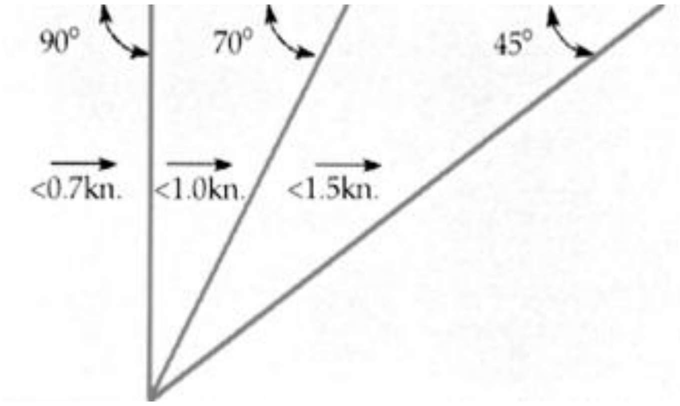

Figure 16 Optimum boom angle

Boom positioning for spill redirection is quite challenging in conditions of scattered and broken ice. A collision with ice may damage the boom which could make further containment impossible. Other problems which might be encountered with this tactic include further mixing of the oil with ice pieces, higher ice concentrations in the boomed area, and presentation of the oil and ice mixture to the skimming mechanism in a way which prevents the oil from being readily collected. Manual manipulation of the ice at the skimmer intake is sometimes possible when ice pieces are small.

As with any boom used in ice, a highly durable fabric with high tensile strength, smooth-sided boom design, and heavy duty connectors are the key features of the boom.

This configuration is carried out by two vessels at sea. One vessel releases the boom into the water, and the other vessel picks up one end. This formation represents a completely deployed boom system (see Figure 17 below). The entire system is deployed perpendicular to the path of the oil slick. When oil reaches the boom, both vessels will drift at the same speed together with the oil. The vessel located down-current from the drift deploys an Arctic Skimmer (with or without the floats depending on actual ice conditions) and recovers the oil.

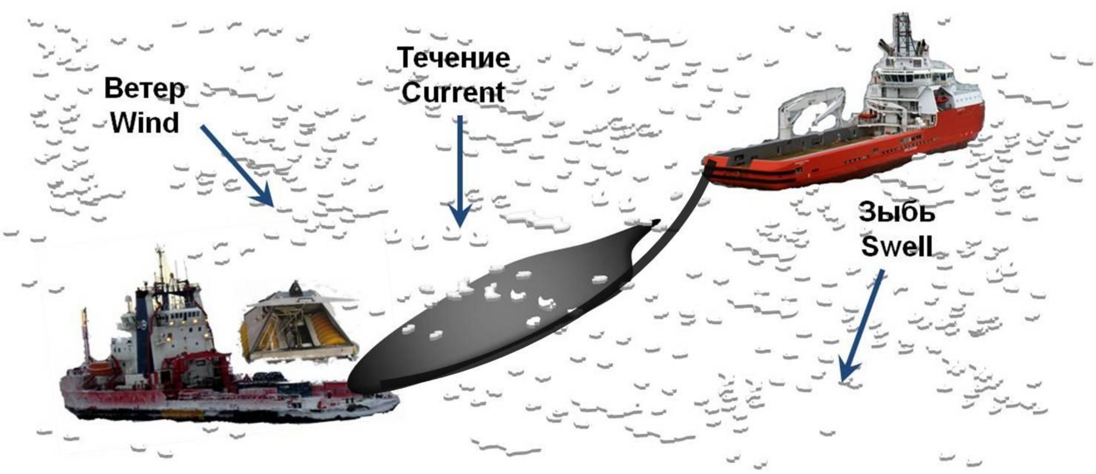

Figure 17 Boom deployment tactic to deflect the slick and redirect the oil to a collection point

This tactic appears like a "very open" U-formation. It is relatively complex in terms of organization and implementation and requires a great deal of experience and training. The vessels have to be equipped with a system of differential positioning to control their speed and position relative to each other to prevent excessive forces acting on the booms.

The deployment of booms is quite difficult under conditions of scattered and broken ice and may be impractical due to ice concentration, the size of ice pieces, and the direction of drift. However, this strategy could be successful for small spills or in the absence of strong currents.

Under ice conditions, booms used for slick redirection must have a solid structure such as oceanic heavy-duty booms (HDB). Even booms with these characteristics may be damaged and their efficiency under ice conditions may be limited.

Recommended ice concentration is not more than 20%. Responders on-site must consider the actual conditions and adapt their deployment tactics to fit the circumstances of the spill. High ice concentrations, particularly with larger floes diverted by the current and winds, can preclude this approach in spite of comprehensive preparations.

Drifting and Recover Tactic

When ice concentrations increase beyond 6/10, ice can provide a natural barrier against the spread of oil. This natural containment offers an advantage for recovery operations in responding to small spills, using skimmers deployed directly from the side of a vessel.

When high ice concentrations make it impossible to deploy booms, a different tactic must be applied. A response SBV approaches the oil slick and determines the direction of slick drift. Subsequently, an Arctic Skimmer is deployed into the oil so that it drifts together with the slick skimming off the oil as the vessel moves at the same speed as the ice. This configuration generally can be used successfully in wind velocities of 10 knots or lower; as wind speeds approach 15-20 knots, however, the vessel may be pushed at a higher velocity than the ice is moving (called "windage") and the opportunity to skim oil is lost.

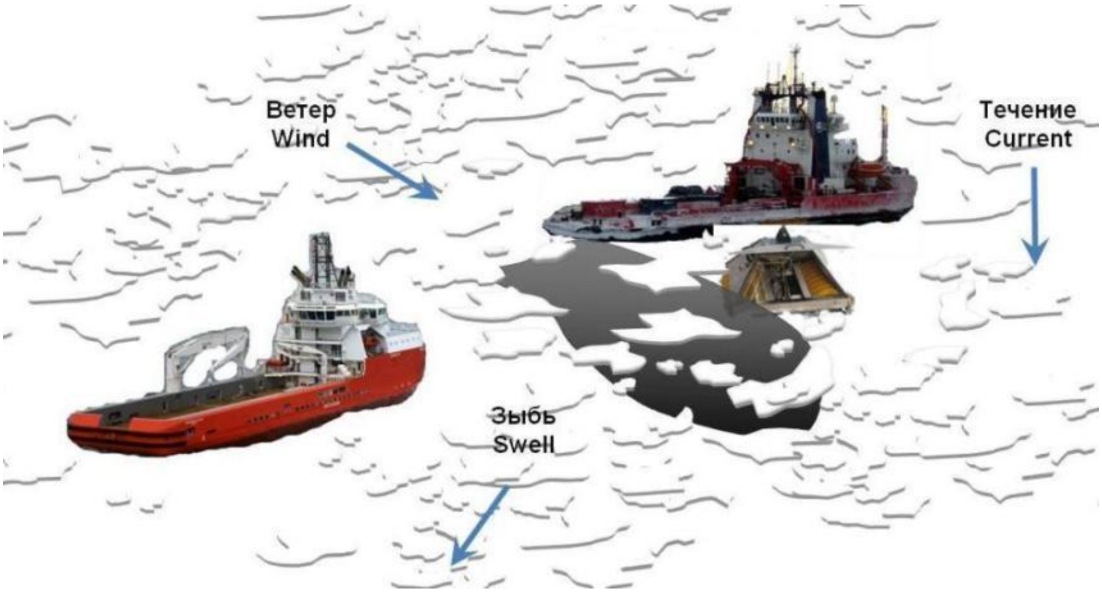

Figure 18 Response tactic using Arctic Skimmer without boom deployment

Recover

Skimming systems

Oleophilic skimmers use belts, disks, brushes, and rope mops of oil-attracting material to remove the oil from water surface.

The oil is then scraped off into a storage chamber or reservoir. These devices are efficient, and it is common for them to result in a high recovered oil-to-water ratio. This type of skimmer takes up a minimum amount of water (generally 1-5%). Light to medium-viscosity oils are most suited to these systems although very high viscosity oils can be handled with certain fittings. Oleophilic skimmers used by Sakhalin Energy are shown below.

The **Arctic skimmer** (LAS) is based on the technology of brush wheels which have proven to be excellent in oil spill recovery operations. It operates most effectively in ice conditions where the oil slick is accessible between ice formations. The lower part of the pump is protected by a durable grid which can even break through compact ice. The skimmer has the ability to deploy steam enhancement. This steam can be used in low temperature conditions, or when it is necessity to work with high viscosity products such as weathered oil.

This Arctic oil recovery system has been designed specifically for operation in extreme cold environments and high concentrations of ice. The skimmer is placed in ice by a ship own deck crane, which also regulates the depth of the skimmer's immersion. This type of skimmers may also be used with floats on ice-free water.

Figure 19 LAS bottom grid for breaking ice (Sakhalin Energy Oil in ice training, P-A field, December 2007)

Figure 20 LAS deployed in ice (Sakhalin Energy Oil in ice training, P-A field, December 2007)

Figure 21 Deployment of LAS in ice (Sakhalin Energy Oil in ice training, P-A field, December 2009)

Minimax skimmer selectively picks up oil from the water surface. The collected product usually contains 5% water. This double brush oleophilic skimming system is not affected by small pieces of ice – the ice either flows under the skimmer, or the small ice pieces which are collected are processed by an auger-type pump. A limitation of using the Minimax skimmer (see Figure 22 below) is the plastic body which can be damaged by ice chunks. Therefore, Minimax skimmer are only deployed in brash ice (i.e. small ice pieces and fragments) or in an essentially ice-free polynya.

Figure 22 Minimax Oleophilic Brush Skimmer (SBV Smit Sibu, 2009)

Weir skimmer collects liquid at the surface of the water. Round floats hold the collection bucket at a level which allows oil to slip over the edge and into the collector. These units are less efficient than oleophilic skimmers and collect a significant amount of water with the oil, requiring additional storage capacity. A benefit of weir skimmers, however, is their ability to handle both light and heavier oil products.

These skimmers pump oil and water which pass over a threshold ring weir. Initially, the floats must be adjusted to position the ring edge on the water surface to minimize the amount of water flowing into the sump. The operator can also adjust the working depth of the skimmer based on pump speed and so controls the oil skimming process and, to some extent, the amount of water collected.

Weir skimmers can recover oil at high rates, but they also collect more water than oil (often in excess of 95%), especially when a thin layer of oil is floating on the water surface. This creates the need to separate the collected water from oil and to discharge it back into the sea. Otherwise, the recovered liquid will quickly exceed the available storage volume of tanks.

Weir skimmers are best employed where oil is concentrated in deep pockets, where it is present in great volume at ice edges, or where booms can be deployed, provided that sufficient storage capacity is available.

Weir skimmers can process small ice particles. A grid installed on the top of the skimmer prevents ice pieces the size of a fist or bigger from entering the skimmer, while smaller ice pieces can be processed with an auger-type pump. Potential problems with screens and grids used to eliminate debris and ice with weir oil recovery devices are the frequent blockages which can occur which prevent oil from entering the skimmer.

Optimally, a weir skimmer is deployed in an area of open water, or between floes where oil has accumulated and concentrated in thick layers. In this situation, a weir skimmer is able to effectively recover oil with a minimum content of water. While the skimmer is in the water, its immersion depth, position relative to the oil, and the ice concentration around it has to be monitored continuously to prevent damage to the skimmer’s body. Wind and ice drift require monitoring since changes can quickly occur. A crane is usually used to deploy the skimmer so that it can be quickly deployed, easily positioned, and quickly retrieved, if necessary.

The Weir skimmer used by Sakhalin Energy is shown in Figure 23 below.

Figure 23 Weir Skimmer (Sakhalin Energy, Oil on water surface training, P-A Field, October 2011)

Storage

An important factor for an effective containment and recovery operation is the availability of storage capacity on board the skimming vessel. The storage volume relative to the recovery capability of the skimming system being used is critical. For example, weir skimmers are prone to collecting large volumes of water relative to oil and can rapidly fill storage tanks. The nature of the recovered product plays an important role in determining transfer and storage requirements. Heavy oils can be difficult to handle, particularly in cold temperatures. Specialized pumps may be required to allow the recovered product to be removed (e.g. LAS used together with a Karcher high-pressure unit which supplies hot water to the pump to heat recovering oil). The separation of water from recovered oil, also known as decanting, into a temporary storage system for retreatment is important for extending the operating capability of individual skimming systems.

If tanks of responded SBV are full, a PSV may temporarily store spilled oil in its tanks and transport the collected spill products to a port for offloading.

The equipment used for transfer operations include the following: pumps, hoses, fittings, and a fendering system. The number of oil transfers should be kept to a minimum to reduce the risk of secondary spills.

Extensive experience and skills of vessel crews are required during mooring and bunkering operations in order to carry out the transfer and storage of spilled oil products collected from the water. A vessel-to-vessel transfer poses significant safety concerns and requires planning and trained personnel to be executed properly.

Towable on-water storage includes barges, bladders, and other storage devices. Marine-based storage systems are not applicable in ice because of the high potential risk of damage and loss of buoyancy due to ice encounters.

Tanks of a SBV is an option which must be considered for any spill. The following tanks are capable and classified for receipt of recovered Vityaz type oil spill with a flash point of less than 60°C: ORO Tanks and Cargo Fuel Oil Tanks. Receivers on deck to fill the tanks are arranged so that there is no possibility of a free fall of the oil/water mixture into the tank which could generate static electricity. The vessel should be equipped with appropriate means to heat the oil spill contained in above volumes for subsequent removal with portable pumps through manholes in the deck. Heat input should be capable of raising the spill volume temperature by at least 5°C in one hour.

Decon

The Warm Zone will be on the deck of a SBV, with the Hot Zone on one side of the vessel and the Cold Zone on the opposite side. Decontamination Zone for equipment and Responders clean up must be placed at her aft cargo deck. The Pond (oil barrier) located on the stern should be used for these purposes. Its purpose is to contain the oil-water mixture during clean-up of oiled equipment. The contained oil-water mixture should decant to an under-deck recovery tank. Examples of such a pond (pool) are given in the Figure 24 below.

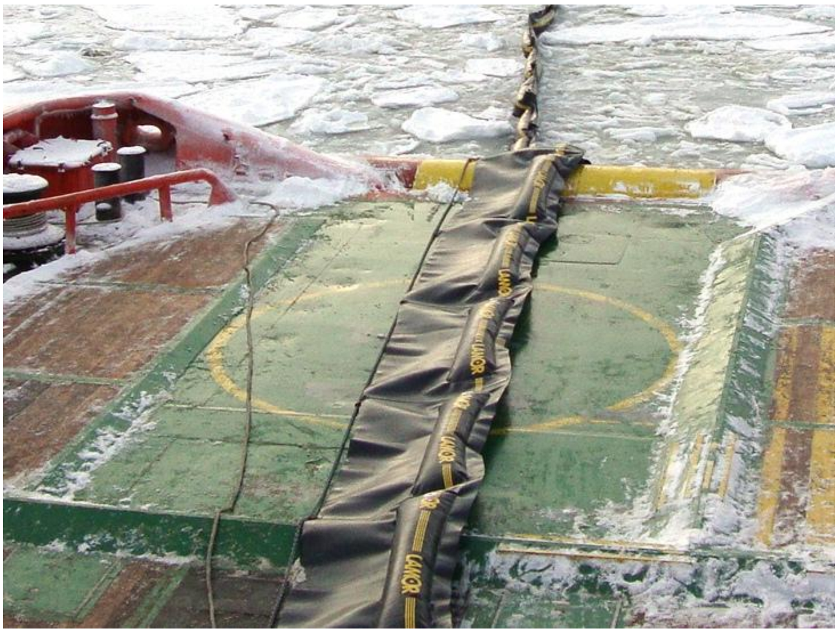

Figure 24 Stern Pond onboard of SBV Smit Sibu (Sakhalin Energy, December 2009)

The photograph shows that, however well snow and ice are removed from the deck, the danger of slippage, either on a flat wood icy deck or a snowy slippery metal surface, must be compulsory taken into account.

RESPONSE TACTIC: SHORELINE PROTECTION

In the event of an oil spill, it is vital to protect the shoreline from contamination whenever possible. The primary response strategy for all oil spills is to contain, recover, or eliminate oil on water as close to the source as possible.

Shoreline and coastal sensitivity to offshore spills in the winter is sharply reduced by the presence of a protective barrier of land-fast ice. For much of the winter, there is no credible pathway whereby oil spilled offshore can directly impact the shoreline. Even a narrow fringe of land-fast ice (hundreds of meters), which often occurs along the NE Sakhalin shore, is enough to prevent direct oiling of the beach.

If oil cannot be prevented from reaching the shore, the main priority is to minimize impacts on the shoreline environment. In cold temperatures, the timing of response operations will vary based on the season and whether or not ice and snow are present.

Any clean-up decision process must balance environmental concerns, needs of local communities, operational practicality, and safety. The Net Environmental Benefit Analysis (NEBA) process is important. To a large extent, the same strategies and tactics typically used in warmer environments apply to ice and cold-climate shorelines. However, the selection of clean-up options depends on the character of the shore zone and the presence of ice and snow. Tactics which can be used to treat or clean shorelines are the following:

Natural Recovery

Allowing shorelines to recover naturally is often the least damaging alternative for light and moderate spills, particularly where access is limited or difficult. This strategy may be appropriate when:

- treating or cleaning spilled oil may cause unacceptable levels of environmental damage;
- response techniques would not be able to accelerate natural recovery; or
- response personnel would be put in danger.

Physical Removal

One tactic for removing oil from the shore is flooding and washing stranded oil into adjacent water where it can be contained and collected. Manual removal may also include collecting oil using shovels and rakes, cutting oiled vegetation, and using passive sorbents; this tactic (including site entry, delineation, containment, storage, decon, and waste issues) is very similar to the RESPONSE TACTIC: MECHANICAL RECOVERY ONSHORE described in the next section.

RESPONSE TACTIC: MECHANICAL RECOVERY ONSHORE

The objective of a response on land is to remove spilled oil which is absorbed or covered by snow.

General actions include phased implementation of the following:

- assess the type of spill indicated by initial detection methods (the source, whether or not the spill is continuing, moving downwards, or stationary);
- perform surveys of the area, including thickness of snow cover and other features which responders should be aware
- delineate the spill extention, using visual methods;
- prepare storage for the collected product, and identify where it can be conveniently and safely set up;
- identify access roads to the area;
- select methods for removal and ultimate disposal of collected spill materials;
- mobilize and deploy equipment and personnel; and
- commence spill containment and removal.

OSR operations will be carried out, depending on the spill location, by personnel using equipment available at the facility in the area where the spill occurred, or with capabilities and resources obtained from other, more distant depots.

The absorbing features of snow should be used to advantage during a land operation in which snow is present. Note that snow types vary greatly and can range from heavy wet slush which can freeze or thaw to accumulations of light crystalline flakes. The capacity of snow to retain oil and act as a sorbent varies correspondingly. Use snow to create fixed berms and dikes, and if the temperature is below zero, mix partially and heavily polluted snow, thus creating a loose mass for effective removal.

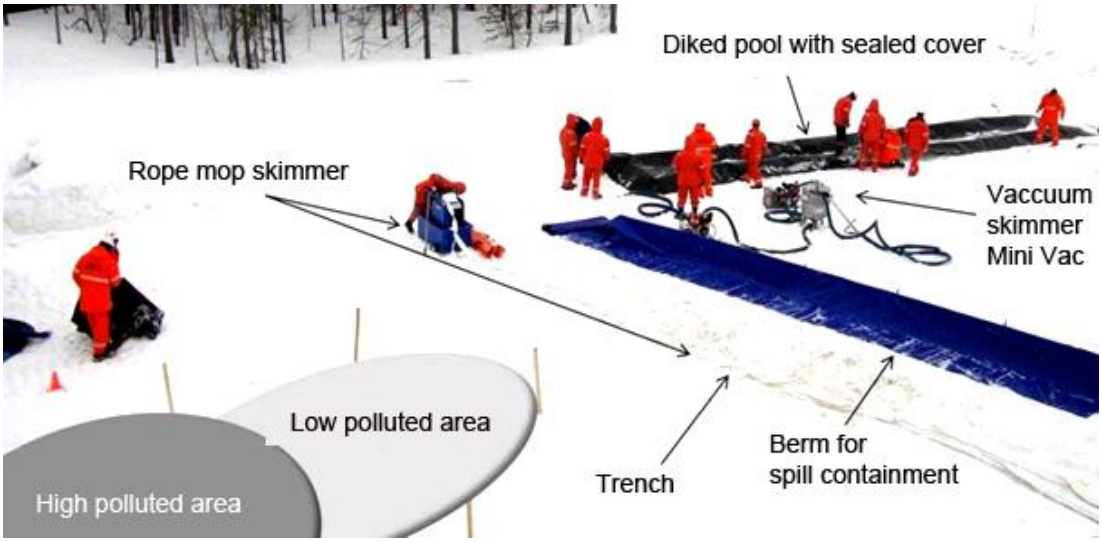

Figure 25 Overview of on-land OSR operations (Oil in snow training, Sakhalin Energy, May 2010)

Site Entry

Control boundaries must be established for any spill site to ensure that Responders and the public are not exposed to the spilled substance. Three distinct zones should be established around the spill site:

- Hot Zone (Exclusion Zone/Working Zone) – control perimeter established where site safety assessment and site entry criteria have been applied.
- Warm Zone (Contamination Reduction Zone/Decontamination Zone) – allows for a orderly transition from the Hot Zone to the Cold zone: Responders and equipment are decontaminated.

- Cold Zone (Support Zone) – free of contamination: support facilities, staging area, warm-up shelters, bathroom facilities, and mobile command post.

Figure 26 below depicts how zones should work.

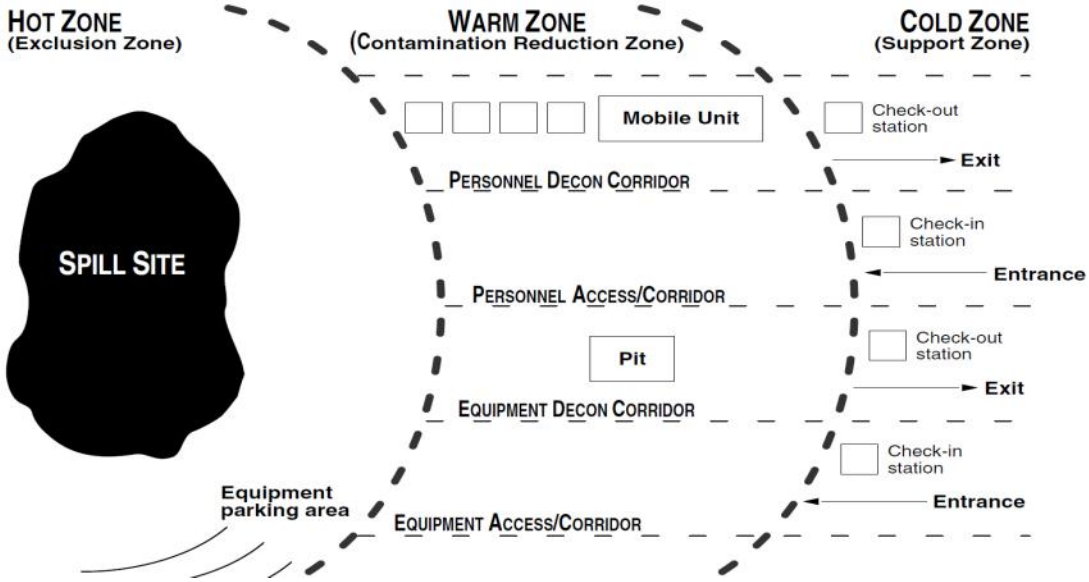

Figure 26 Spill site zones layout (STAR Manual 2006)

The following guidelines should be considered when establishing site layout and control:

- The Hot Zone should be as small as possible to prevent the spread of contamination, but large enough to accommodate emerging conditions, such as migration of the spilled product or changes in the direction of the wind.
- The Hot Zone should provide for parking/storage of contaminated equipment in order to minimize decontamination until the work is completed.
- Walking boards or other type of traffic control will assist in minimizing the spread of contamination with the Hot Zone.
- To the extent possible, warm zone facilities should be located up-wind and up-hill from the Hot Zone.
- Security should be established around the Hot and Warm Zones.
- Check-in/check-out procedures should be established for all personnel and equipment entering the Hot Zone.
- The “buddy system” should be used to account for all personnel in the Hot Zone.

Recon

When oil is released onto frozen ground or ice, its behaviour is predictable; it will spread over the surface. An oil plume will migrate over time, driven by topography or wind.

If a spill is detected at the Pig Trap Station (PTS), oil may be covered with snow. If a spill is detected several days after a snowfall, oil might have been displaced by wind to a relatively significant distance from the spill source, and possibly in various directions due to changes in wind direction.

Probing with a shovel may reveal several alternate layers of packed snow and oil. Therefore, Responders must carefully recon a spill site to determine affected areas.

The delineation procedure begins after spill borders are determined, and removal operations start at the border of the area determined to contain oil.

Delineate

The objective of delineation is to determine the extent and trajectory of an oil spill plume both on the surface and subsurface. This tactic may be used on land and on solid ice.

The area of an oil spill in snow must be clearly defined and delineated in such a way that the oil may be found following subsequent snowfall or snow drift.

Delineation tactic are used when a spill occurs on ice or snow by mapping plume borders. If the plume has distinctly different levels, layers, or concentrations, plume sections should be mapped separately.

Plume edges are marked on a drawing, map, or sketch; on the site they are marked with surveyor's stakes. Different coloured stakes or flagging tape may be used to indicate borders of distinctive layers or concentrations of the plume. Simultaneously, a record is made for each stake location using a handheld GPS device. A hand-drawn map is sketched in the field to assist in developing final maps using computer applications.

Figure 27 Delineation in snow cover (Oil in snow training, Sakhalin Energy, May 2010)

Contain

When crude oil spills on snow, it is absorbed since snow is a good natural sorbent. The amount of oil that can be absorbed depends on the type of snow and type of oil. New, soft snow may absorb oil in an amount equal to its own weight. Oil of medium viscosity will be absorbed by snow in higher concentrations than refined oil. Oil content will be lowest in packed snow at temperatures well below zero, and highest in new snow at temperatures near or above freezing point.

The addition of crude oil to snow raises the melting point of the snow. Compared to gasoline, crude oil causes more melting, but it spreads less. Gasoline moves more quickly in snow and covers a larger area.

Severe snowfall may complicate OSR operations. In this case, it is recommended that only heavily contaminated snow be collected with snow removal in less polluted areas being postponed until spring. Fresh snow falling in a less contaminated area may be used to help contain the spill.

Dikes and Berms

Dikes and berms are land-based strategies involving the creation of non-natural barriers. Snow is used to contain spills and limit their spread, see Figure 28 below.

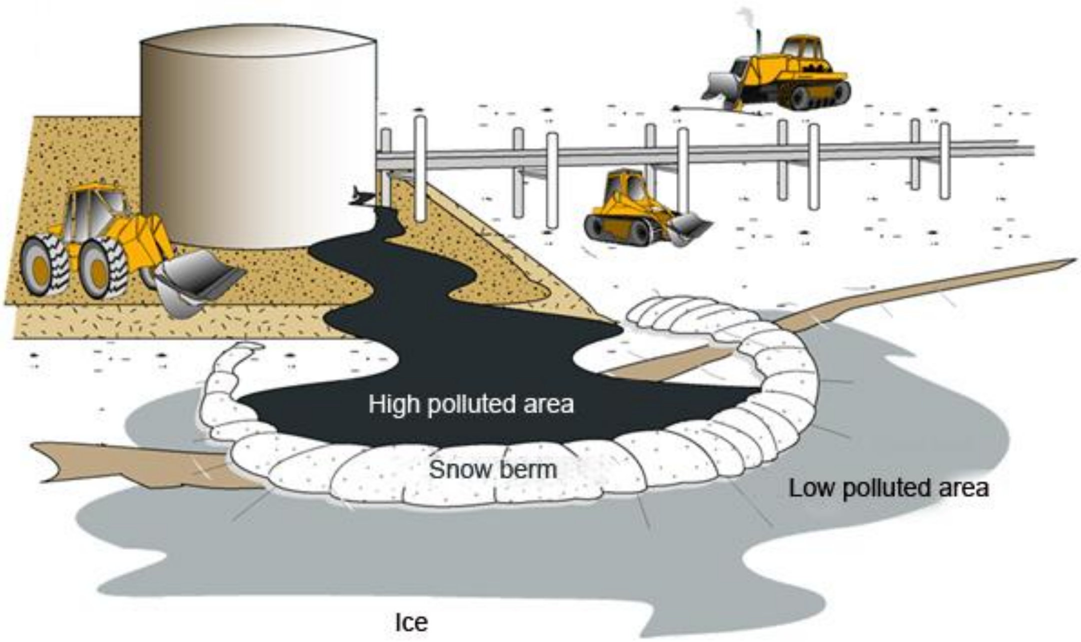

Figure 28 Snow berm (adapted from STAR Manual 2006)

This strategy may be applied on land as well as on river ice and can be used in conjunction with a recovery tactic (skimmers, sorbents) or an excavation tactic (pits, trenches, slots). The dike and berm strategy is most effective when dikes and berms are in place to intercept oil before it arrives.

Dikes and berms can be constructed using a variety of materials including: soil, gravel, snow, sand bags, booms, timber, and logs. Selection of the construction material depends on the operating environment, location, available materials, and whether such a structure is to be temporary or permanent. The containment area should be lined with an impermeable membrane such as plastic sheeting to prevent penetration by oil and oily water.

Dikes and berms may be constructed by hand or using excavators, depending on site location and available resources.

Snow and ice combined with sand and soil are suitable construction materials for embankment structures on thick ice and frozen soil, but other construction materials can also be used. Iron berms with liners are also available. A snow berm can be reinforced by spraying water on it to form an ice crust on the surface of the snow.

Recover

At a PTS the use of heavy machinery for collecting contaminated snow might be difficult due to the limited space for manoeuvring. Therefore, hands-on collection of contaminated snow with shovels may be the most suitable response tactic.

Use hand tools and small containers for small spills. At a large spill with access available, use loaders and dump trucks for snow collection and transportation to a disposal site.

If snow melts, use a vacuum skimmer, or move snow into a pit or temporary storage tank. If oil is ice-bound, use an excavating machine to access the oil plume and initiate its recovery.

Standard equipment used for on-land recovery consists of earth-moving equipment (from shovels to heavy machinery), skimmer systems, and sorbents.

Figure 29 Snow removal by backhoe excavator (Sakhalin Energy OSR training on land and ice)

Storage

Appropriate and reliable systems for onshore storage and transfer of spill liquids are an important part of OSR operations. Equipment for storage and oil transfer has to be selected carefully to provide the required storage volume and continuous flow of liquid oil spill products. Inappropriate or insufficient storage and inadequate transfer systems may severely impact the continuity of the OSR process.

The selection of storage systems depends on the type of spill, the expected speed of recovery, and the duration for which temporary waste storage is needed. Analysis of the area includes working conditions as well as distance and height which the liquid has to be transferred to.

The portable tanks in Figure 30 below are made of oil resistant synthetic materials such as urethane and nitrile. Portable tanks are cylindrical, foldable storage containers made of an impermeable material which is supported by a collapsible metal frame. These tanks compact when stored and are easy to transport and deploy. Storage volume capacity is from 7.5 to 10.5 m3. However, portable tanks are sensitive to abrasion, punctures, and damage if not properly maintained. A level surface is required for their installation.

Figure 30 Example of Sakhalin Energy portable tank with a storage volume of 10.5 m3

Pits and pools with a sealed cover (e.g. plastic liner) on the bottom and walls can be used for temporary storage of oily liquids and wastes. The walls of the pool can be created by diking with sand bags and snow. Pits can be excavated as well if material to construct walls is difficult to obtain or not available. The inside of the pit must be lined with a layer of impermeable and oil-resistant material. It should have a top-cover to prevent the accumulation of snow and must be inspected frequently for leakage and available volume. A pit is designed to be used only as temporary storage; accumulated waste should be removed from it as soon as possible. After use, it should be cleaned and disposed of. Pits are constructed in situations when the volume of oil exceeds the volume of available storage tanks. They can also be used as storage when no other alternatives are available.

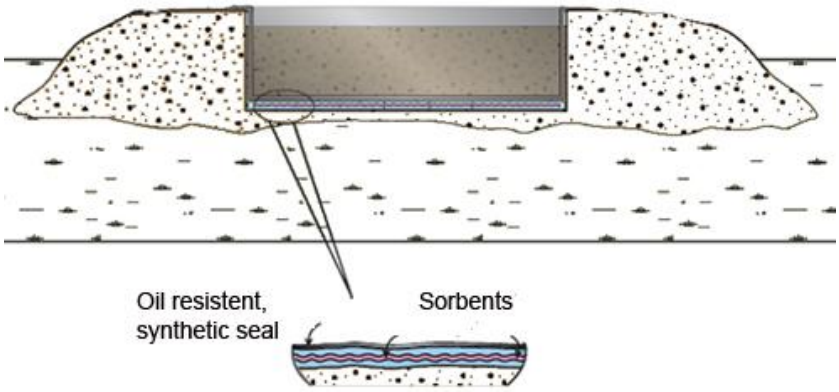

Figure 31 Diked pool with plastic liner used as temporary storage (adapted from STAR Manual 2006)

Figure 32 Pool constructed in snow with plastic liner (Oil in snow training, Sakhalin Energy, May 2010)

Barrels made of steel or aluminium and plastic tanks are preferred for long-term storage. There is a stockpile of fish totes on PMDs which can be used for this purpose, as shown in Figure 33 below.

Figure 33 Plastic fish totes are used for storage of plastic bags with oiled snow (Oil in snow training, Sakhalin Energy, January 2009)

The recovery of oiled snow and ice can create a large volume of waste which contains only small amounts of oil. One option to minimize the waste stream is to melt and decant the ice and snow on site.

Decon

Decontamination involves the removal of oil or other contaminants from Responders and equipment after they leave the Hot Zone. The purposes of decontamination are to:

- minimize Responder contact with contaminants;
- prevent spread of contaminants to clean areas and exposure to personnel there;
- remove contaminants from equipment to allow its reuse.

Decontamination is conducted in the Warm Zone, which is the control point for personnel and equipment entering and leaving the Hot Zone.

In general, personnel and equipment move through various steps of decontamination to ensure that gross contamination is removed first, and that uncontaminated clothing and equipment do not become contaminated by the decontamination process.

Decontamination will take into account the following deployment issues:

- plan for containment, collection, and disposal of contaminated solutions and wastes generated from decontamination;
- separate decontamination stations to prevent personnel cross-contamination;
- develop distinct entry and exit points, and physically separate entry paths from contaminated area to clean area and vice versa;
- establish procedures for minimum decontamination for restroom use and medical emergencies;
- locate medical/first aid stations to avoid exposure to contaminants;
- use disposable protective clothing and equipment where possible;
- use strippable coatings for equipment where possible;
- use double containerization of contaminated wastes and recovered materials (e.g. plastic liners in overpack drums);
- inspect all PPE for cuts, tears, punctures, abrasions, and other signs of deterioration prior to use or reuse;
- consider placing a containment boom along the shoreline when decontamination is performed adjacent to a water body.
- use plywood walking boards or other similar material to establish pathways for heavy foot traffic areas.

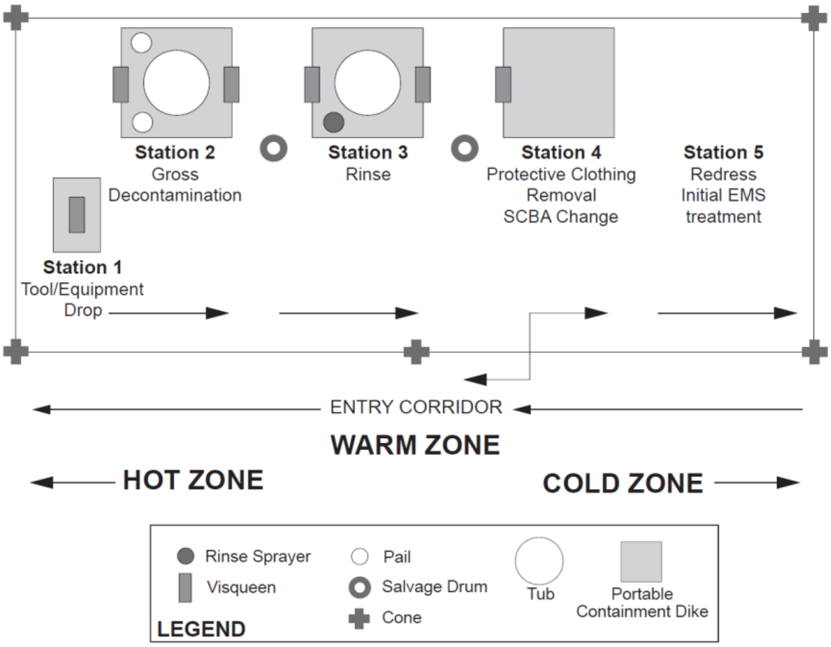

Figure 34 Decon at the spill site (STAR Manual 2006)

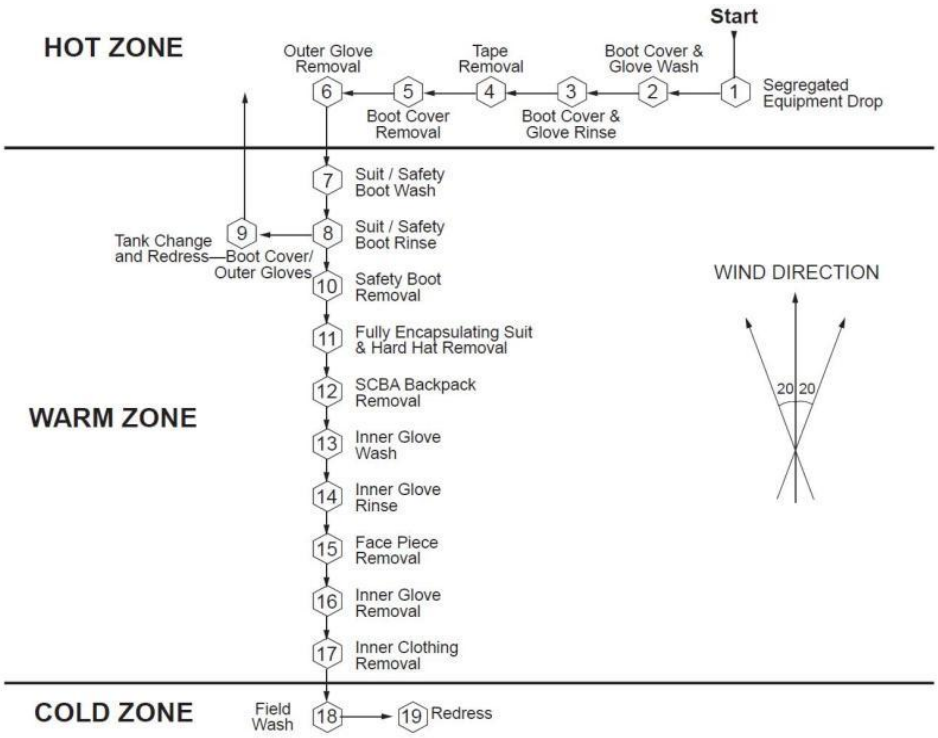

Figure 35 General Decon flow chart (STAR Manual 2006)

Waste

Onshore and shoreline recovery tactic involves the recovery and disposal of collected oiled snow and ice. Manual removal includes collecting oil using shovels. Manual removal is slow and labour intensive, but generates less waste than mechanical removal by heavy machinery.

Mechanical removal techniques essentially use equipment designed for earth-moving. Although clean-up rates are less labour intensive and are much faster than manual removal (which may be factors in remote areas), as much as ten times more waste is generated by mechanical removal, which in itself may be a logistics issue.

RESPONSE TACTIC: MECHANICAL RECOVERY ON ICY RIVERS AND BAYS

Recon

An example of the simplest form of ground-based surveillance of oil under ice is illustrated in Figure 36 below. The crew is drilling at various sites according to a grid and then marking the extent of oiling which they determine to be present.

Figure 36 Recon on river ice (Oil under ice training, Sakhalin Energy, March 2009)

Ice thickness in particular largely determines the load-bearing capacity of sea and freshwater ice. The relationship between the thickness of sea ice and its load-bearing capacity is graphically presented in Figure 38 below.

The general nature of these data is well-recognized. During an incident, assessments would be undertaken of the condition of the actual ice present by Responders to consider whether the ice is forming or melting, the presence of cracks, roughness, and other anomalies, floe size, wind and ice velocity, and other relevant factors prior to the ice being used as a platform for OSR operations.

When working on ice, it is important that the thickness is known. Figure 37 below demonstrates an ice measurement technique. The ice is drilled into until water is reached and a measuring stick is inserted into the hole. Measurements are repeated at several locations according to a simple grid, and then a decision is made on the safety of operations based on the previously-noted factors.

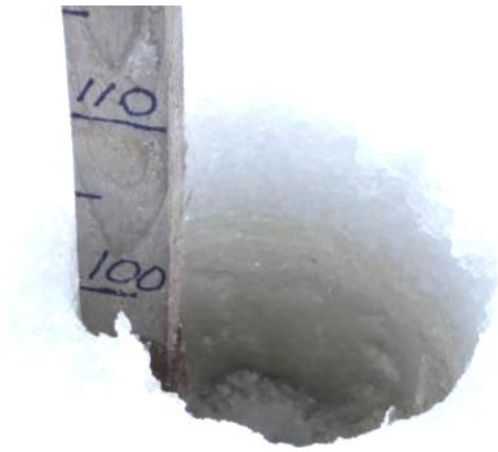

Figure 37 River ice thickness measurement (Oil under ice training, Sakhalin Energy, March 2009)

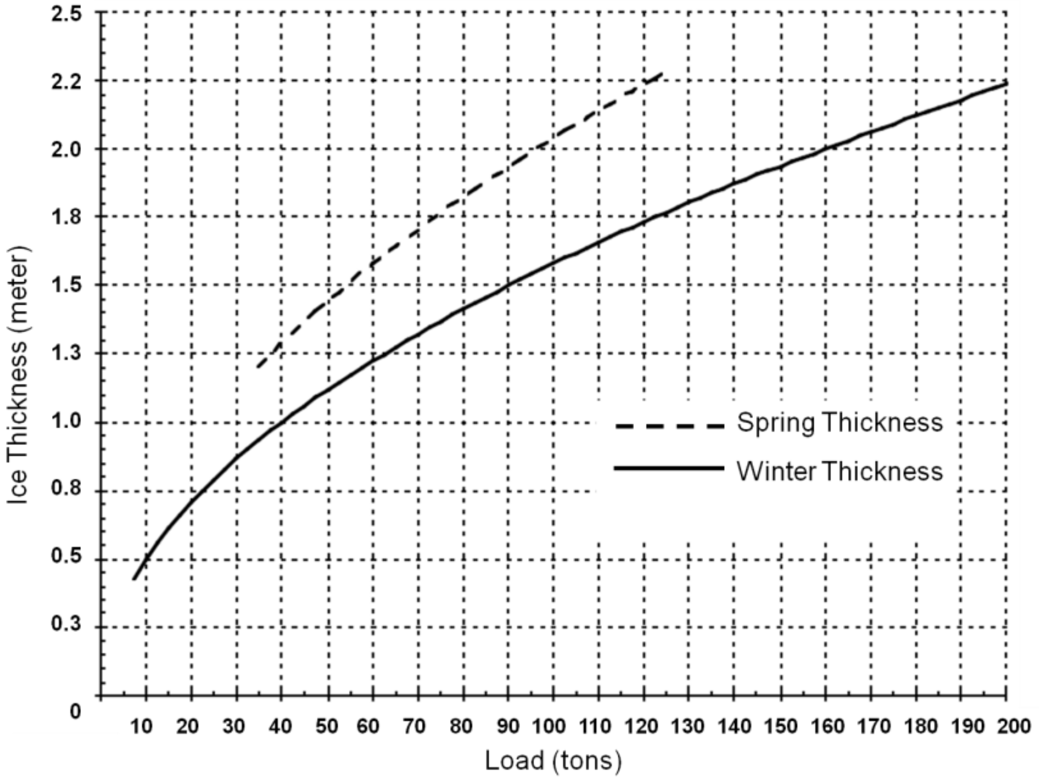

Figure 38 Load bearing capacity of sea ice (adapted from STAR Manual 2006)

The ratio between thickness of freshwater ice and load-bearing capacity can be observed in Figure 39 below.

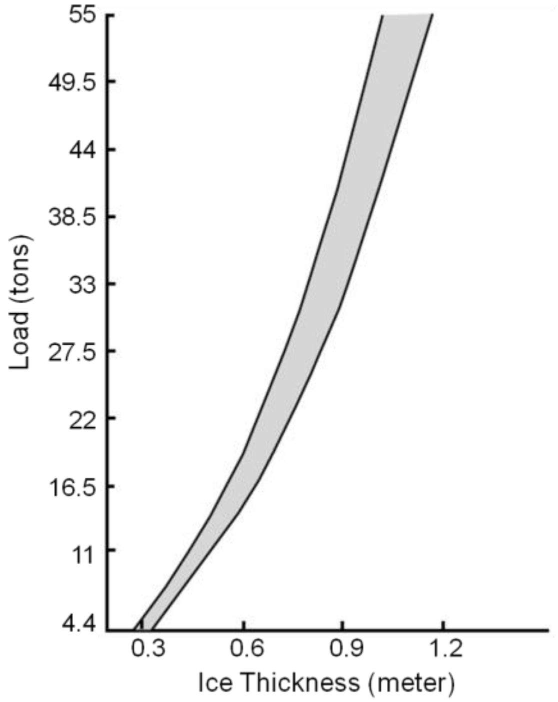

Figure 39 Load bearing capacity of freshwater ice (adapted from STAR Manual 2006)

Delineate

The objective of Delineation is to determine the extent and trajectory of an oil spill plume both on the surface and subsurface. This tactic may be used on land and on solid ice.

For assessing the probable location of the spill and the area of possible migration of oil slicks, a grid may be used like it shown on Figure 40 below.

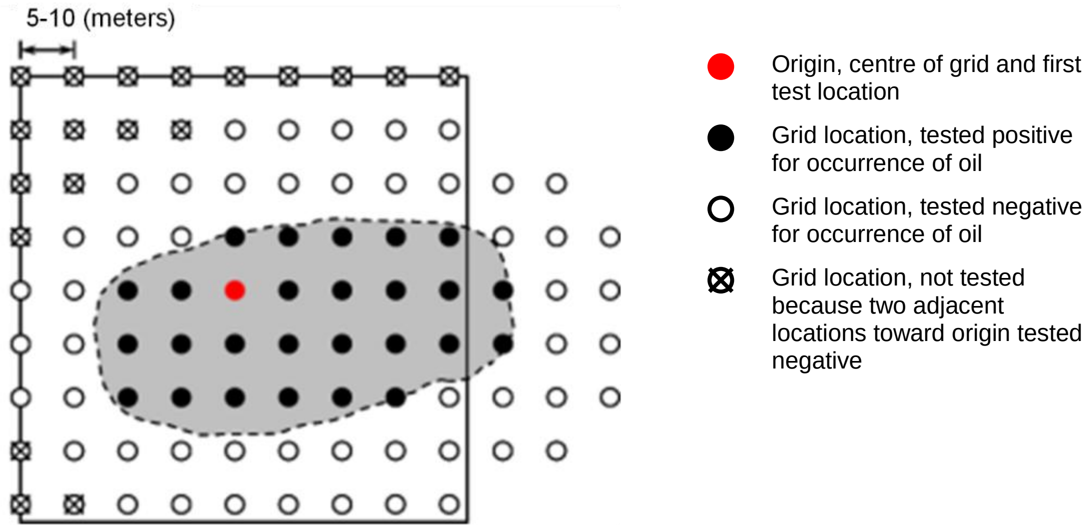

Figure 40 Delineation using a grid of holes for a detection and delineation of oil under ice (adapted from STAR Manual 2006)

If the perimeter of the spill cannot be seen because it is under snow or ice, a different approach is required. First assess the probable location of the spill and the surrounding terrain to determine the likely migration path of the plume. In this case a grid may be used to delineate the plume. The grid is first laid out from a starting point where the spill is known or suspected to have occurred. From this origin, the grid is set in all directions. The grid is established with stakes set a consistent distance apart. The grid should be set at the required spacing – for example, on Sakhalin rivers 1.5 m is recommended. If the spill is huge or Responders are working on the ice of a bay or big river (e.g. Tym River), the grid steps and overall spacing can be increased accordingly.

Contain

Trenches, channels and slots

Trenches, channels, and slots should be utilised for containment and recovery of accumulated oil. Rather than building a barrier, a depression or channel is excavated down-slope/down-current from the spill for oil to accumulate in. The tactic uses the local topography to direct oil to areas where it will accumulate. It can be applied on land and on ice-covered waters.

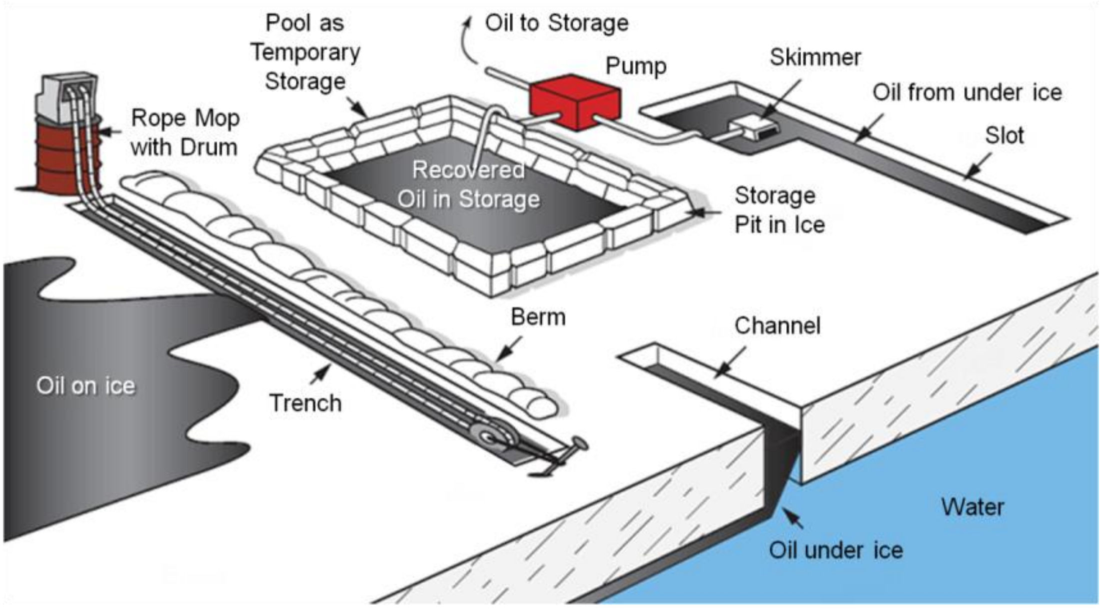

Figure 41 Overview of tactics used on ice and sometimes on land (adapted from STAR 2006)

Figure 42 Overview of tactics used on ice to catch oil under ice (Oil under ice training, Sakhalin Energy, March 2009)

Trenches can be excavated by heavy machinery. Channels in the ice are cut by Bobcat machines using the saw adapter (see Figure 43 below), or portable saws can be utilized. The use of Bobcat machines on ice requires that complex issues of ice thickness are assessed. If the ice is a concern, then the door of the Bobcat should be taken off, and the operator should not use a seatbelt when operating on ice. Whether to use a Bobcat or not is decided by the Site Controller or On-Site Commander with consideration of the Safety Officer’s advice.

Figure 43 Trench cutting for deploying booms in ice (Oil under ice training, Sakhalin Energy, March 2009)

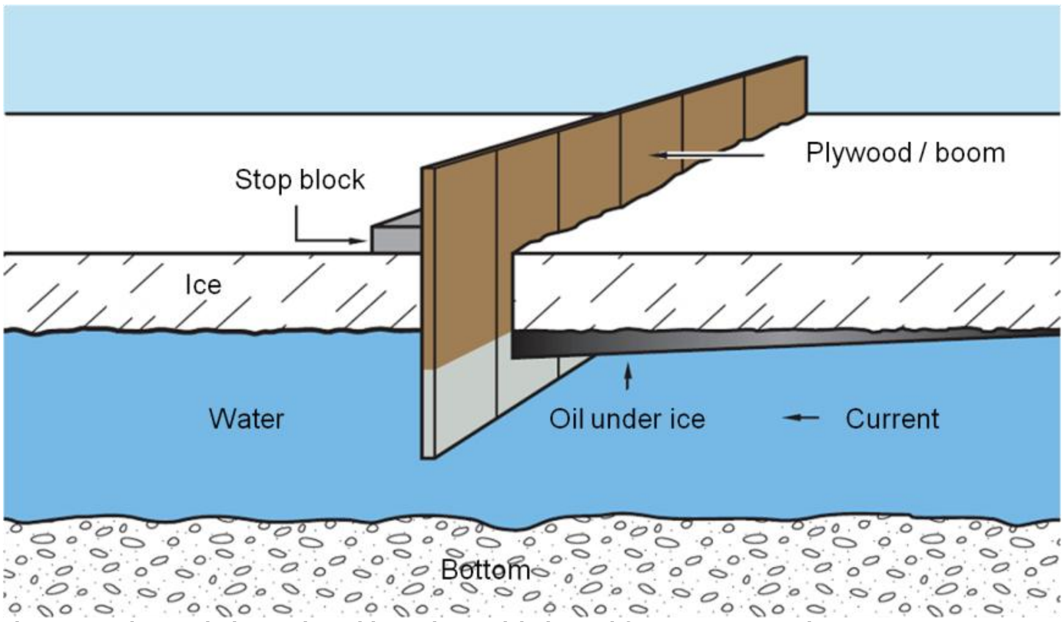

Figure 44 Plywood sheet placed in a channel (adapted from STAR 2006)

An oil resistant, synthetic liner can be placed in a natural depression or excavated pit to prevent oil from penetrating into the soil. Usually, this is not required in ice conditions. A liner creates a physical barrier to prevent oil migration (see section Dikes and Berms). When oil starts to accumulate in a trench or a channel, recovery operations can use an appropriate skimmer system suitable for the specific oil type and concentration.

Recover

Trenches are dug in conditions which allow for construction of structures with steep walls. The trenches can be deeper than pits; trench depth will create a higher column of oil, facilitating effective collection. Trenches are also used to divert oil into pits.

Channels are typically used on ice-covered water bodies where oil is concentrated underneath. A channel is cut through the ice towards the accumulated oil.

When snow cover is present, oil will be absorbed by the snow which therefore must be collected. Oil flowing into a trench may require planning for additional storage volume. Storing solid contaminated materials separately must also be planned. Not all spilled oil flows into a trench or is contained within a channel, so removal of spreading oil and oil-absorbed snow will be required.

An under-ice boom (see Figure 45) may be installed for better containment of oil if the current velocity under the ice is high or a large amount of oil is expected, and the containment channel itself is too small to accommodate the spill volume. Sheets of plywood of up to 2 m in height (see Figure 42 and Figure 44) can generally be used on ice with a thickness of over 70 cm.

Slots are typically used on ice-covered waters to remove oil which is trapped underneath. A slot is cut through the ice for oil to accumulate in. The slot may be cut at an angle to reduce the relative velocity of the oil and allow it to rise up into the slot. Plywood can also be inserted into the ice to act as a containment barrier for oil moving under the ice.

Generally, a current ≥0.5 knot is required to move oil under an ice cover. If the current is not strong enough, oil will collect in pockets under the ice. In this case, a slot can be cut above the pocket.

The site must be determined to be safe regardless of thickness prior to on-ice operations being conducted.

Skimming systems

Minimax skimmer may be used in situations with large enough quantities of spilled oil, or where oil is directed to an opening for accumulation. These skimmers pick up oil as it adheres to a collection surface, leaving most of the water and debris behind. Oil is then scraped from the collection surfaces and pumped to storage facilities. Oleophilic skimmers can be used for any type of oil and can be used for a thin layer of oil on the water surface.

Brushes are less vulnerable to icing, clogging, and malfunctioning than rope mop systems which depend on mops to collect oil and wringers to remove it. Mops can freeze whereas the bristles of brushes remain separated at sub-freezing temperatures, so they can pick up oil which is then removed with a comb-type scraper.

Figure 45 Minimax skimmer in ice hole where oil spill accumulates and under-ice boom placed in a channel cut in ice (Sakhalin Energy OSR in ice training, November 2009)

Oil pools of low and average viscosity on the surface which are covered with snow, oil caught in a trench surrounded by a berm, or oil which has emerged on the surface in a channel can be collected with a vacuum skimmer.

Mini Vac skimmer uses the vacuum principle for oil suction. Vacuum skimmers, like weir skimmers, may pick up large volumes of water and relatively small quantities of oil if they are operated in a thin slick.

Vacuum skimmers can be used for oil recovery in ice. However, their operation may be impeded by the ice when operated in sub-zero temperatures while collecting oil mixed with a high water content. In these circumstances, hoses, fittings, and the inlet or nozzle may also clog up with ice and halt skimming.

Figure 46 Mini Vac Skimmer arrangement (Sakhalin Energy on-shore OSR training in snow, April 2010)

Rope Mop skimmers utilise a rope of polypropylene strands which oil adheres to. Often the collected liquid contains considerable amounts of dirt and slush ice which may cause problems during transfer and storage.

Figure 47 Rope Mop skimmer placed in trench (Sakhalin Energy on-shore OSR training in snow, April 2010)

Storage, Decon and Waste

Storage, Decant and Waste issues are the same as in RESPONSE TACTIC: MECHANICAL RECOVERY ONSHORE.

SAFETY

This Manual addresses the safety issues which must be considered in the first stages of oil spill response in cold weather conditions. The HSE Plan is the main component for a spill response. The plan contains a list of hazards and risks which should help operating personnel implement control and mitigation measures safely and effectively.

Protection of human life and health is the highest priority during oil spill response activities. Sakhalin Energy recognises the importance of safely conducting routine operations and is fully aware that stress may increase due to the extra pressure of emergencies such as OSR.

Storage of alcohol and alcohol consumption at Sakhalin Energy facilities is prohibited under any circumstances at all times of year. Alcohol is NOT first aid treatment for hypothermia.

The main risks during a winter oil spill response are low temperatures, ice thickness on rivers, working on ice of inadequate load carrying capacity, and the extremely dynamic nature of open water and ice concentrations. These elements are crucial considerations when planning safe and effective OSR strategies in cold weather areas in the northern part of Sakhalin.

Basic HSE issues for conditions of cold and ice environments include:

- danger of overcooling and cold injury due to effects of low temperatures and changing weather conditions;
- reduced visibility due to falling or blowing snow and ice;
- reduced mobility and increased amount of energy spent, and the need for more breaks to ensure personnel are sufficiently warmed, rested, nourished, and alert;
- vessel body icing, high ice concentrations, ice movement, and reduced vessel manoeuvrability;
- ice-bearing capacity when people and heavy machinery are working on the ice of water bodies;
- danger of slippage on flat and rough ice and slippery metal surfaces of working decks;
- short daylight hours; and
- risk of disturbing sleeping bears.

Figure 48 Working deck of Sakhalin Energy SBV Smit Sibu (P-A field, December 2009)

The decision-making process during preparations for OSR involves selecting appropriate and effective strategies of deflection, containment, and recovery of spilled oil. It is also obligatory to consider all relevant HSE issues, the feasibility of mitigating themas well as the seasonal and local environmental conditions.

Sakhalin and its northeast (NE) shelf where Sakhalin Energy facilities are located is characterized by cold, severe winter periods, so personnel must use appropriate personal protection equipment (PPE) when commencing work.

However, even routine work might be difficult to carry out in a thermally-insulated outfit. Therefore, it is important to choose the appropriate combination of clothing which enables OSR specialists to execute their tasks without jeopardizing safety. Guidelines for selection and appropriate use of winter PPE are described in Table 1 below.

Clothing fabrics, especially underwear and absorbing layers, must absorb perspiration and transport it away from the skin, thus avoiding discomfort and possible cold stress.

The outer clothing layer provides protection against the environment and must be water and windproof, durable, and have good insulating properties.

It is important to protect extremities like the head, hands, and feet from the cold. Waterproof goggles with double glass and foam plastic trim provide adequate eye protection. Proper gloves and footwear are essential for cold weather response operations.

Table 1 Guidelines for selecting winter PPE

PPE	Requirements
Underwear	Must be comfortable to wear and made from water-wicking fabric. This layer should take perspiration away from the body and keep the skin dry. Synthetic fabrics such as polypropylene are the best choice. Among natural fabrics, wool and silk are good choices. Cotton is not recommended since it absorbs sweat and retains it near the skin.
Absorbing layer	This layer must absorb moisture from the underwear and transfer it to the atmosphere through evaporation. Synthetic fabrics and wool are good. At the same time, this layer must be loose enough to keep warmed air close to the body.
Insulating layer	Outer wear with an insulating layer of several centimetres thickness is recommended to be worn when working in a sitting position or in severe cold conditions. Down clothing and synthetic thermal insulation materials are suitable for this purpose. Note: if down becomes wet, it will lose its insulating qualities, and it is slow to dry. Therefore, synthetic thermal insulation materials are more suitable in wet or moist conditions.
Outer layer	This layer should ensure protection against the cooling effect of wind and water. Non-waterproof fabrics are better in dry conditions since they allow perspiration to evaporate.
Footwear	Boots should have a structure containing several layers: an inner layer made of synthetic fabric, a second insulating layer of synthetic fabric like a removable liner, and an outer layer made of leather or durable synthetic compounds.
Gloves	Gloves must provide sufficient thermal insulation and be comfortable to wear since thick gloves may reduce dexterity of hands and fingers.
Eye protection	Safety glasses with double glass and/or insulated with foam plastic trim and having polyurethane frames.
Face protection	A mask (balaclava) must be worn for maximum protection of the face and neck against cold and wind during extreme low temperatures; it should comfortably cover the chin and face and have a scarf-tube for protecting the neck. The mask has openings for breathing.
Head protection	Hard hats may be required. It is recommended to wear a warm, knitted hat, balaclava or fleece hat under the hard hat.

A person may suffer from cold injuries due to inappropriate use of PPE. This could result in extensive physical damage and severe health problems. Hypothermia is considered to be the most serious consequence of overcooling and, if not treated, may cause death. Hypothermia is a condition characterized by a severe drop of body temperature to levels below 35°C

(95°F). At this stage, the human body loses its warmth faster than it is able to generate it. A person affected by cold stress or hypothermia usually does not notice the direct impact. Symptoms and first aid measures are given in Table 4 and Table 5 below.

Avoiding cold stress and hypothermia is achieved by ensuring that every Responder is trained in using appropriate PPE and knows how to recognize the symptoms of hypothermia. Furthermore, work in cold weather should never be undertaken alone: work in pairs so that colleagues can carefully watch each other.

When planning a response operation, do not rely on weather forecasts to accurately reflect actual weather conditions in the response area. During a cold weather response, it is important to obtain information on local wind velocity. Wind speed has a considerable influence on the cooling effect (wind chill factor) and increases the risk of frostbite – as shown in Table 2 below. High humidity is also a factor which increases the impact of cooling.

Table 2 Cooling impact of temperature and wind speed on human body

Air temperature (°C)	Wind velocity (m/s)	Cooling effect (°C)
–3	10	–20
–10	10	–30
–15	10	–35
–25	10	–50

Snowdrifts can be dangerous for both people and machinery. Personnel trapped in a snow drift on the road should not try to force their way through the mounds of snow. A vehicle should be parked with its engine windward, blinds closed, and radiator covered. Personnel must leave the cabin periodically to shovel snow away to prevent the vehicle from becoming snowed under completely.

In order to be rescued as quickly as possible, a distress call can be made, preferably by means of VHF radio, cell-phone, or satellite telephone. Attaching bright material (e.g. high visibility vest, coloured ribbons, or tape) to a pole or antenna will give search and rescue teams a better visual indication of the position of a stranded crew (see Figure 49 below).The vehicle should not be abandoned if it is unclear whether there is a safer location nearby. The engine should be warmed up periodically to ensure that the exhaust pipe does not become clogged with snow.

Figure 49 Snowstorm during the muster drill at Sakhalin Energy Nogliki PMD (April 2010)

Prior to beginning OSR operations in cold weather conditions, supervisors must establish a schedule for work and breaks, taking into account the need to allocate additional time for task execution and more work breaks, so that personnel can get warmed up and their health monitored.

Recommendations with regard to work and breaks in cold weather conditions are given in Table 3 below. The schedule can be applied to work of average severity to heavy work, with 10-minute breaks for warming up in dry, heated shelters. If work of light to average severity with limited physical movement is performed, it should be assumed that personnel will be more affected by the cold. Therefore, when assessing a work time/break ratio, a temperature value of one position lower than the actual temperature should be chosen from Table 3 below. For example, at –35°C without obvious wind, a worker with limited physical movement should work a maximum of 40 minute intervals with 4 breaks during a 4-hour shift.

Table 3 Work and Break Schedule for Four-Hour Shift

Air temp., °C	W/o wind		Wind 8 km/h		Wind 16 km/h		Wind 24 km/h		Wind 32 km/h	
	Maximum working time, minutes	Breaks, quantity	Maximum working time, minutes	Breaks, quantity	Maximum working time, minutes	Breaks, quantity	Maximum working time, minutes	Breaks, quantity	Maximum working time, minutes	Breaks, quantity
–26 to –28	115	1	115	1	75	2	55	3	40	4
–29 to –31	115	1	75	2	55	3	40	4	30	5
–32 to –34	75	2	55	3	40	4	30	5	Non-urgent work is stopped	
–35 to –37	55	3	40	4	30	5	Non-urgent work is stopped			
–38 to –39	40	4	30	5	Non-urgent work is stopped					
–40 to –42	30	5	Non-urgent work is stopped							
–43 and below	Non-urgent work is stopped									

Outerwear has to be removed in rest areas in order to prevent overheating and increased perspiration. Sufficient sets of clothing changes are required for all personnel involved in field work. Special appliances for drying footwear and clothing (field mobile dryers) must be installed onsite where the response operation is in process.

The human body can experience cold stress as a result of exposure to low air temperatures or after immersion in cold water. Information on prevention of such conditions and application of first aid is given in Table 4 below. Note that the ingestion of alcohol is prohibited under any circumstance at SEIC facilities and is not considered a first aid measure to treat hypothermia.

Table 4 Injuries related to cold, preventive measures and First Aid applications

Description	Symptoms	Prevention	First Aid
Snow blindness (ophthalmia) – damage of conjunctiva and cornea caused by ultraviolet rays of the sun which are reflected by snow crystals.	At first, the victim cannot distinguish differences in surface levels. Secondly, a sensation appears as if fine sand is located under the eyelids. Eyes and eyelids are swollen, eyes are watering and become red. It is extremely painful to look at a light source.	Wear special sun glasses with side blinds. The glasses must be labelled with a "CE" inscription. This guarantees protection against UV emission.	Protect eyes from sunlight. Provide rest for the victim and accommodate him/her in a dark shelter, use lightproof dressing. A cool lotion may be used to ease the pain. As a rule, symptoms reduce within 1-2 days, and the disease disappears completely within 4-5 days. Usually, snow blindness does not result in permanent blindness. Eyesight will completely recover. However, increased sensitivity to light often remains.
Cold burn – quick, superficial freezing of tissue when it is in contact with an extremely cold metal object.	In many cases, cold burns are similar to burns caused by high temperatures; they do not compromise health and are not life-threatening. Freezing onto metal is possible. In this case, a cold burn injury will be more serious compared to a burn from a hot object where a person instinctively pulls away the affected body part.	Use gloves. Do not touch metal objects with uncovered parts of the body.	Injured body part must be immersed into warm water of 40-42°C for approximately 10 minutes.
Trench foot – damp-cold injury of lower extremities (e.g. feet), which is caused by prolonged exposure of feet to damp and cold conditions. This medical condition usually occurs at moderate ambient temperatures.	The first stage is manifested within 14 days (sometimes within in 3-4 days) after wearing cold, damp boots. Characterized by pain, abnormal sensitivity and muscular weakness. The second stage is accompanied by oedemas, blisters, and redness of the skin. Both stages are reversible.	Wear dry, waterproof, and appropriately sized boots. Timely change of socks and/or boot liners.	Accommodate the victim in a warm shelter. Remove frozen boots and socks. Warm up the extremities and dry injured feet. Apply heatproof dressing (gauze layer, thick cotton layer, gauze layer, and an oilcloth or rubberized material on top). Do not open blisters (this may cause infection). Transport to a medical facility as soon as possible.
Frostbite – a cold injury which causes superficial or deep damage of tissues. This cold injury is called frostbite at early stages. Frostbite may occur not only in ambient temperatures below zero but at temp. of 4-8°C.	Toes, fingers, ears, and nose are usually affected by frostbite. People often do not feel frostbite symptoms until they enter a warm shelter and get warmed up.	The appropriate PPE described in Table 1 should be used in the correct manner. Adhere to work and break regime as specified in Table 3. Be vigilant while working in pairs, when each has to monitor his/her colleague's condition.	Accommodate the victim in a warm shelter. Remove frozen boots, clothing, and jewellery (a wedding ring may cause further necrosis of a finger). If a heated shelter is provided, the injured area can get warmed up quickly. Direct heat of the body directly on the injured area – i.e. by putting a warm hand onto a frostbitten cheek, nose, or ear, or keeping a frostbitten finger under an armpit; a foot can be

Superficial frostbite is characterized by skin damage. Ears, nose, cheeks, toes, and fingers are usually affected first.	With superficial frostbite a person experiences a burning, itching, or prickling sensation, numbness of the frostbitten part, and a sense of cold. Examination reveals grey or yellowish skin areas, usually on the nose, ears, cheeks, fingers, or toes. Underlying tissues remain soft and flexible.		rested against a warm belly. Do not rub extremities. Warm (but not hot) water (40 °C) is the best warming agent. Do not allow the affected area to warm up too quickly. Except for severe cases, normal colour and sensitivity of frostbitten skin returns within in 20-30 minutes after warm water application. If there is a danger that the affected body part will be re-frozen, it is better to leave tissue frozen than to freeze and unfreeze the same area several times. This could result in more serious injuries. Under such circumstances, cover the frostbitten tissue with a soft bandage or liner. Apply sterile and dry dressing (gauze layer, thick cotton layer, gauze layer, and oilcloth or rubberized material on top) on the injury. If fingers or toes are frostbitten, put cotton or gauze between them. Provide warm drink without caffeine, which disturbs blood circulation. Check ingredients of the drink – e.g., Coca-Cola contains caffeine. Transport to a medical facility as soon as possible.
Deep frostbite – skin and subcutaneous tissues are damaged. It entails complete or partial freezing of the body part.	Frostbite might be noticed when the body part felt cold and painful and then suddenly stops hurting, although it does not become obviously warmer. With deep frostbite the following symptoms can be observed: oedema, blisters, and white or yellow skin which looks like wax and after defrosting becomes a blue or purplish colour. The skin becomes hard and dead; blackened skin is seen. Freezing of superficial and deeper tissues. Tissue injury of various degrees may occur, including necrosis which requires amputation.		

Table 5 Hypothermia, preventive measures and First Aid applications

Stage	°C	°F	Symptoms and organism response	First aid
Normal	37	98.6	Standard temperature of the body for normal functioning of organism.	Not required
Mild	36	97	Impairment in ability to think rationally, forgetfulness.	Provide IMMEDIATE medical treatment. Move the injured from the cold environment to a heated shelter; remove his/her frozen and wet clothing. Cover him/her with insulating material (blanket, dry and warm clothing), especially the extremities. If a person can swallow, give him/her a warm drink without caffeine. Do not immerse the body in hot water. In order to ensure gradual and natural warming up, put the victim into a sleeping bag together with another healthy person whose body will act as a heat exchanger. Breathing has to be monitored carefully at a moderate and severe degree of overcooling. If necessary, begin artificial respiration and closed-chest cardiac massage. If signs of frostbite on extremities are observed, appropriate care should be given Table 4), but only after hypothermia symptoms have subsided. Transport to a medical facility as soon as possible.
	35	95	Hypothermia threshold. Metabolism disorder and depression of vital functions. Shivering, rapid pulse, impaired judgement, unclear speech.	
	34	93	Awkward movements, disorientation, the victim stumbles and falls down. Apathy, estrangement. Violent shivering which transits to muscular tension. Inappropriate behavior – e.g. removing clothing.	
Moderate	33	91	Bluish skin, weak pulse, extremely slow breathing rate, low blood pressure, unfocused mind, delirious speech, violent shivering.	
	32	89	Cardiac arrest is likely. Loss of body temperature will continue, if protection against cold is not provided. Extremities become numb and cold.	
	31	87	Loss of consciousness. Further pulse slowdown, blood pressure drop, unstable heartbeat.	
Severe	30	86	Difficulties in detecting pulse and breathing	
	28	83	Fixed, enlarged pupils (not contracted under light).	
	24	75	Irreversible changes occur. Cardiac arrest, termination of brain activity. If further temperature drop is observed, chances for survival are unlikely.	

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